ISSN 0377–9335

Vol. 33 March 2008 No. 1

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Centre for Arthropod Bioresources and Biotechnology (CABB),
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ENTOMON

ENTOMON is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other arthropods.

Address MS and all editorial correspondence to Managing Editor, ENTOMON, Centre for Arthropod Bioresources and Biotechnology (CABB), University of Kerala, Kariavattom, Trivandrum 695581, India.

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ENTOMON **33(1):** 1–13 (2008)
Article No. ent.33101

Mortality and fertility life tables of leaf folder *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) in rice

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ABSTRACT: Identifying key natural enemies and vulnerable life stages of leaf folder are essential for careful planning and developing practical management programs. The present study is an attempt to construct a life table of natural populations of rice leaf folder in India, to delineate and quantify the role of various mortality factors. Analysis of life table data of rice leaf folder based on natural field populations revealed various mortality factors responsible for the fatality of leaf folder at different stages. *K*-values indicated that the total generation mortality was 72.33% in *Dry* and 54.15% in *Wet* seasons, of which biotic factors contributed 34.06% and 29.72% mortality while other factors resulted in 38.27% and 24.43% mortality in the two seasons, respectively. Series of stage-specific mortalities showed maximum mortality in the pupal stage (k_{7+8} = 0.2957 in *Dry* and 0.211 in *Wet* seasons) followed by late larval stage (k_{4+5+6} = 0.1716 in *Dry* and 0.1202 in *Wet seasons*). Bio-mortality factors included seven parasitoids, one pathogen and five predators. Of these, pupal parasitoids viz., *Brachymeria* sp. and *Xanthopimpla flavolineata* Cameron were the key mortality factors causing 34.15% mortality in *Dry* and 32.35% in *Wet* seasons. Survival rates from greenhouse studies indicated higher mortality early in the life cycle i.e., egg and larval stage. Total generation mortality was 26.1% in *Dry* season and 25.9% in *Wet* season indicating that ≈ 75% of the population entered into the next generation under greenhouse conditions. Intrinsic rate of natural increase (r_m) was 0.183 females per female per day and the finite rate of increase (λ) was 1.2008 females per female per day.

KEYWORDS: mortality factors, parasitoids, pathogens, net reproductive rate, intrinsic rate of increase, survival rates, *Cnaphalocrocis medinalis*

INTRODUCTION

Rice leaf folder, *Cnaphalocrocis medinalis* Guenee is widely distributed in all the rice growing tracts of South and South-east Asia. Once considered as minor pest,

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it has now attained a major pest status due to intensification of rice cultivation and outbreaks of this pest have also been reported (Khan *et al.*, 1988; Senapati and Panda, 2006). Life tables provide an important tool in understanding the changes in population of insect pests during different developmental stages throughout their life cycle. Identifying key natural enemies and vulnerable life stages of leaf folder are essential for possible biological control efforts and for careful planning and developing practical management programs (Midega *et al.*, 2005; Medieros *et al.*, 2000; Hu *et al.*, 2000). Characterization of stage specific survivorship is also important for reflecting the impact of natural enemies in economic thresholds (Pedigo, 1997).

Determination of population increase from reproductive capacity is another crucial component in the study of insect populations. Population increase can be described by a fertility table that gives the potential reproductive ability of females at different times. A standard estimator for the growth rate of insect populations is the intrinsic rate of increase (r_m), which describes the maximal rate of increase at any time interval under optimal conditions. The rate of multiplication of a population per generation is described by the net reproductive rate (R_o), which is dependent on r_m (Southwood, 1978).

Though there are a few earlier reports on biology and life cycle aspects of leaf folder (Barrion *et al.*, 1991; Pang *et al.*, 1981), information on life table of the pest is lacking. The present study was carried out to determine the variables of life and fertility tables to be used as a basis for understanding the population dynamics of *C. medinalis* in rice and may help in finding the reasons for flare up of this pest.

MATERIALS AND METHODS

Mortality tables

Greenhouse and field studies were conducted at Directorate of Rice Research, Hyderabad during Wet (*Kharif*) and Dry (*Rabi*) seasons of the years, 2004 and 2005.

Greenhouse studies

To assess the inherent mortality of rice leaf folder, age-specific life-tables were constructed from the data recorded on the same cohort under the greenhouse conditions (23 ± 10 °C temperature and 60 ± 10% relative humidity) coinciding with Wet and Dry seasons. Paired adults were released for oviposition on 20–25 day old susceptible variety i.e., Taichung Native-1 (TN 1) plants placed in wooden cages (66 cm length ×97 cm width ×86 cm height) having wire mesh on all sides. Eggs from the same cohort were considered for this life table study. There were three replications in each season. The leaves of plants with eggs were tagged and these potted plants were kept in wooden cages in the greenhouse. The tagged eggs were observed daily till they hatched. The larvae were observed till they pupated. Mortality data were recorded at each stage. The pupae were collected and placed in test tubes and were observed for the emergence of adult moths. The number of males and females emerged were counted to know the sex ratio.

Field studies

The experimental field consisted of 750 m^2 area with a susceptible variety i.e., Taichung Native-1 (TN 1) planted in nine blocks of 80 m^2 area each. Each block is considered as one replication and thus there were nine replications per season. The rice crop was raised following recommended agronomic practices without any plant protection measures. Absolute populations of leaf folder and that of its natural enemies were recorded in both Wet and Dry seasons of both the years. Due to overlapping generations of the pest, life tables were prepared for seasons instead of generations. In each block, one square meter area was marked at two places, of which one was kept open and the other area was covered on all four sides by a polyethylene sheet to restrict the larval movement. The top portion was kept open for movement of natural enemies. The stages sampled in the field included different larval instars, pupae and adults that emerged from collected pupae. Observations were initiated at first instar stage and continued till pupation, at four-day interval. All the leaves of each plant (40 hills) in one square meter area were inspected for folded leaves with larvae. The number of healthy surviving larvae in folded leaves was counted and allowed to remain in the field, while the morbid/parasitised larvae were collected and reared individually in laboratory, for emergence of adult parasitoids. Similarly, in subsequent observations the healthy larvae that pupated were collected and brought to laboratory and observed for adult emergence while parasitized pupae were separated and pupal parasitism was estimated. The number of males and females that emerged from pupae was counted to determine the sex ratio. The emerged adults were then paired and kept for oviposition.

To assess the mortality at egg stage, pots with TN 1 plants having leaf folder eggs (0–24 h old) were placed in the field at random for about two days. Predators found during sampling were also visually counted to provide an estimate of potential predators in the study area. At larval stage, the differences in larval population observed in open and closed areas were considered due to larval dispersal. Based on these data, stage specific mortalities were worked out after grouping first two instars of *C. medinalis* larvae as 'early instars' and rest three as 'late instars'. Analysis to recognize the role of various factors in life table was done as suggested by Varley and Gradwell (1960). Series of stage specific mortalities (k-values) for egg, larvae and pupae were then summed up to compute the total generation mortality (K) in the life-table of the leaf folder. Means were computed by pooling the data of four seasons of both the years.

To know the effect of abiotic factors on leaf folder population, meteorological data *viz.*, maximum temperature, minimum temperature, relative humidity (morning and evening), rainfall and sunshine hours were recorded. Correlations were worked out between larval population and the weather parameters.

Fertility table

Age specific fertility or fecundity parameters were recorded on TN 1 variety under greenhouse conditions. Leaf folder adults that emerged on the same day from the field collected pupae were paired and released for oviposition on 20–25 day old TN 1 plants

covered with cylindrical mylar cage. Adults were fed with 20% honey solution inside cages. Ten such pairs were used for the study in each season. The number of eggs laid by a female was counted and adults were released daily on fresh plants till their death. After hatching, larvae were allowed to develop by providing fresh TN1 plants as and when necessary. The number of females born (mx) out of the eggs laid by a female was calculated based on these observations.

Based on the data obtained, mortality and fertility life-tables were prepared according to Harcourt (1969); Southwood (1978); Hu *et al.* (2000); Medieros *et al.* (2000) and Midega *et al.* (2005). The net reproductive rate (R_o), approximate generation time (T_c) and capacity for increase (r_c) were calculated as per Ghosh *et al.* (1995) and Mohanty *et al.* (1995). The accurate value of r_m was calculated by taking two arbitrary trial values on either side of the value for R_o differing only in the second place and substituting them in the formula. Graphically r_m value was estimated according to Narendra Reddy and Singh (1998). By using accurate r_m value, the true generation time (T) and finite rate of increase (λ) were further calculated. The time taken (in days) for the leaf folder population to double was also worked out.

RESULTS

Mortality tables

Greenhouse studies

Life-table of leaf folder under greenhouse conditions is summarized in Table 1. Females lived for about a week with pre-oviposition period of 3–4 days and oviposition period of 4–5 days. Total development period from egg to adult was found to be 24.8 days. Survival rates indicated higher mortality early in the life cycle i.e., egg and larval stage (Fig. 1). Hatching percentage of 84.69 and 82.03 was found in the two seasons. Total generation mortality was 26.1% in *Dry* season and 25.9% in *Wet* season indicating that *ca.* 75% of the population entered into the next generation.

Field studies

Analysis of field life table data based on natural populations revealed several mortality factors responsible for the fatality of leaf folder at different stages (Table 2). K-values indicated that the total generation mortality was 72.34% in *Dry* and 54.15% in *Wet* seasons, of which biotic factors contributed 34.06% and 29.72% mortality while other factors resulted in 38.28% and 24.43% mortality in the two seasons, respectively. Series of stage-specific mortalities showed maximum mortality in the pupal stage (k_{7+8} = 0.2957 in *Dry season* and 0.211 in *Wet season*) followed by late larval stage (k_{4+5+6} = 0.1716 in *Dry* and 0.1202 in *Wet seasons*).

Bio-mortality factors included seven parasitoids, one pathogen and five predators. Of these, pupal parasitoids *viz.*, *Brachymeria* sp., *Xanthopimpla flavolineata* Cameron and *Tetrastichus* sp. were the key mortality factors causing 34.05% mortality in *Dry* and 32.85% in *Wet* seasons of the total pupal mortality (Fig. 2). Parasitism was

TABLE 1. Life table of leaf folder under greenhouse conditions

Stage of the insect (x)	*Number living (lx) Mean ± SE(m)		Factors responsible for dx (dxf)	*Number dying (dx)		dx as % of lx (100 qx)		kappa (k) values	
	Dry season[$]	*Wet season*[#]		*Dry season*	*Wet season*	*Dry season*	*Wet season*	*Dry season*	*Wet season*
Eggs	122 ± 1.15	85.34 ± 0.33	unhatched	18.67 ± 0.34	15.34 ± 0.33	15.30	17.97	0.073 (k_1)	0.086 (k_1)
Larvae	103.34 ± 1.76	70 ± 2.88	unknown/natural	19.34 ± 0.88	11.67 ± 0.34	18.70	16.67	0.090 (k_2)	0.0792 (k_2)
Pupae	84 ± 1.15	58.34 ± 0.88	unknown/natural	11.67 ± 0.34	8 ± 0.57	13.88	13.71	0.065 (k_3)	0.0641 (k_3)
Adults	72.34 ± 1.76	50.34 ± 0.34	deformed	5.34 ± 0.33	3.34 ± 0.33	7.37	6.62	0.033 (k_4)	0.0297 (k_4)
Adults	67 ± 1.16	47 ± 0.57							
				Total generation mortality (**K**)				0.261	0.259

*Mean of two years (three replications/season)
$ Dry season (*Rabi*) – November to April of 2004 and 2005
# Wet season (*Kharif*) – July to October of 2004 and 2005

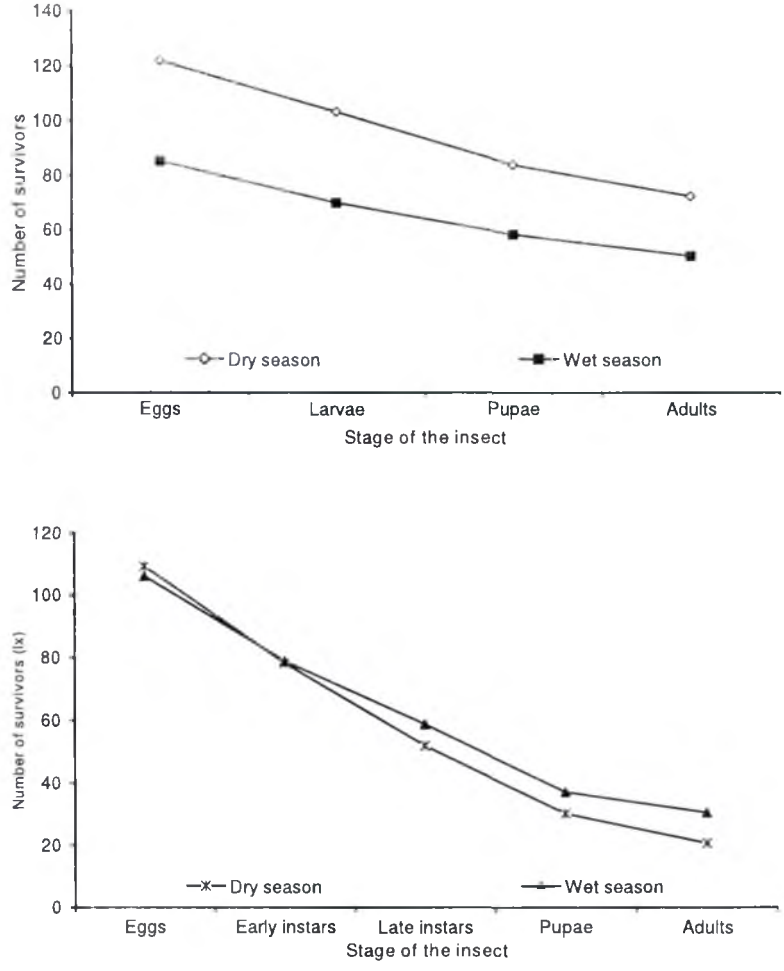

FIGURE 1. (a) Survivorship curve – greenhouse; (b) Survivorship curve – Field.

also high in late larval instars (20.88% in *Dry* and 17.27% in *Wet seasons*) due to *Macrocentrus philippinensis* Ashmead and *Goniozus* sp. In early instars, *Apanteles angustibasis* (Gahan) and *Apanteles* sp. caused 8.54% (*Dry season*) and 8.7% (*Wet season*) mortality. The lone pathogen recorded was *Beauveria bassiana* (Balsamo) Vuillemin causing 3.71% and 1.89% mortality of late larval instars in the *dry* and *wet* seasons, respectively. Predators included one spider (*Tetragnatha* sp.), beetles (*Paederus* sp., *Ophionea* sp.) and damsel flies at all the stages.

Larval dispersal was relatively higher during early instars (8.24 to 12.93%) compared to late instars (6.59 to 11.57%) in both the seasons. Blackening of pupae resulted in the mortality of pupae (23.16% in *Dry* and 9.08% in *Wet*) while

TABLE 2. Life table of rice leaf folder under field conditions

Stage of the insect (x)	*Number living (lx) Mean ± SE(m)		Factors responsible for dx (dxf)	*Number dying (dx)		dx as % of lx (100 qx)		Kappa (k) values	
	Dry season[$]	*Wet season*[#]		*Dry season*	*Wet season*	*Dry season*	*Wet season*	*Dry season*	*Wet season*
Eggs	109.33 ± 0.67	106.12 ± 0.45	Unhatched	23.33 ± 0.57	20.25 ± 0.59	21.34	19.08	0.1042(k_1)	0.0920 (k_1)
Early instar	86 ± 0.62	85.87 ± 0.71	Parasitism	7.77 ± 0.32	7 ± 0.46	9.04	8.15	0.0411(k_2)	0.0369(k_2)
larvae	78.23 ± 0.52	78.87 ± 0.56	Dispersal	10.11 ± 0.42	6.5 ± 0.33	12.93	8.24	0.0602(k_3)	0.0374(k_3)
Late instar	68.11 ± 0.61	72.37 ± 0.44	Parasitism	14.22 ± 0.32	12.5 ± 0.37	20.88	17.27	0.1018(k_4)	0.0823(k_4)
larvae	53.88 ± 0.63	59.87 ± 0.59	Pathogen	2 ± 0.37	1.13 ± 0.29	3.71	1.89	0.0164(k_5)	0.0083(k_5)
	51.88 ± 0.54	58.74 ± 0.53	Dispersal	6 ± 0.62	3.87 ± 0.29	11.57	6.59	0.0534(k_6)	0.0296(k_6)
Pupae	45.88 ± 0.48	54.87 ± 0.59	Parasitism	15.67 ± 0.53	17.75 ± 0.36	34.15	32.35	0.1813(k_7)	0.1697(k_7)
	30.22 ± 0.40	37.12 ± 0.56	Blackening	7 ± 0.41	3.37 ± 0.32	23.16	9.08	0.1144(k_8)	0.0413 (k_8)
Adults	23.22 ± 0.40	33.75 ± 0.44	Deformation	2.55 ± 0.26	3.25 ± 0.25	10.98	9.63	0.0505(k_9)	0.0440 (k_9)
	20.67 ± 0.50	30.50 ± 0.56							
				Total generation mortality (**K**)				0.7234	0.5415

*Mean of two years (nine replications/season)
$ Dry season (*Rabi*) – November to April of 2004 and 2005
# Wet season (*Kharif*) – July to October of 2004 and 2005

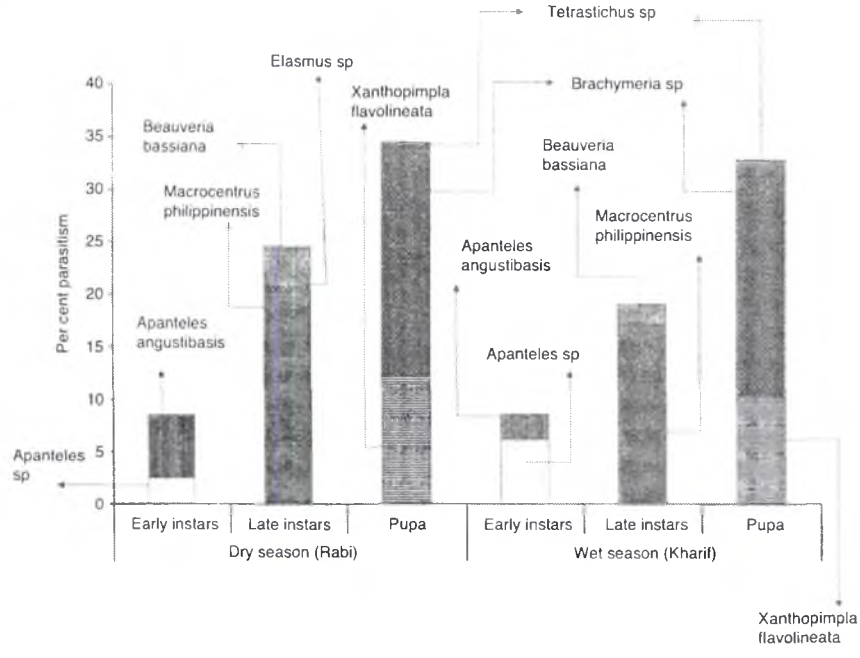

FIGURE 2. Stage specific parasitism of rice leaf folder.

deformation of adults was another factor accounting for 10.98% in Dry season and 9.63% mortality in *Wet* season.

Correlation between leaf folder population and weather factors indicated that the maximum temperature ($r = -0.6977$), minimum temperature ($r = -0.5781$) rainfall ($r = -0.6702$) and sunshine hours ($r = -0.5798$) have significant negative relationship while morning relative humidity ($r = 0.6719$) and evening relative humidity ($r = 0.7501$) exhibited positive relationship.

Fertility table

Female moth started laying eggs after 27th day of pivotal age which lasted up to 33rd day with lx values being 0.56 to 0.04, respectively (Table 3). The maximum mean progeny production per day (Vx) was 71.93 females per female on 29th day of pivotal age. The net reproductive rate (R_0) was 210.77 indicating that the population of *C. medinalis* would be able to multiply 210.77 times per generation (Table 4). The mean length of generation (T_c) was 29.24 days. Intrinsic rate of natural increase (r_m) was derived as 0.183 females per female per day (Table 4 and Fig. 3). The finite rate of increase (λ) was 1.2008 females per female per day. The population multiplied 3.6 times per week and doubled in 4.75 days.

TABLE 3. Age specific fecundity table of *Cnaphalocrocis medinalis*

Pivotal age in days (x)	l_x	m_x	V_x $(l_x m_x)$	$x.l_x m_x$	Trial r_m values		Accurate value
					$r_m = 0.18$	$r_m = 0.19$	$r_m = 0.1830$
					$e^{7-r} m^x . l_x m_x$	$e^{7-r} m^x . l_x m_x$	$e^{7-r} m^x . l_x m_x$
0–25	0.56	–	–	–	–	–	–
26	0.56	–	–	–	–	–	–
27	0.56	–	–	–	–	–	–
28	0.56	94.06	52.67	1474.76	373.92	282.60	343.7952
29	0.56	128.45	71.93	2085.97	426.53	319.16	390.9945
30	0.42	141.82	59.56	1786.80	295.00	218.54	269.6120
31	0.37	63.05	23.33	723.23	96.52	70.79	87.9475
32	0.12	24.02	2.88	92.16	9.95	7.23	9.0412
33	0.04	10.15	0.40	13.20	1.15	0.83	1.0457
Total			210.77	6176.12	1203.07	899.15	1102.4361

l_x—Number of living females
m_x—Number of living females born per female in each age interval
V_x—Total number of female births in each age interval
r_m—Intrinsic rate of increase

TABLE 4. Life table parameters

S.No	Population growth statistics	Formula	Calculated value
1	Net reproductive rate (R_0)	$\Sigma l_x m_x$	210.77
2	Mean length of generation (T_c)	$\Sigma x l_x m_x / R_0$	29.30 days
3	Capacity for increase (r_c)	Loge R_0 / T_c	0.1826 females/ female/ day
4	Arbitrary r_m values	0.18 & 0.19	
5	Intrinsic rate of increase (r_m)	$\Sigma e^{7-r} m^x . l_x m_x$	0.1830 females/ female/ day
6	Finite rate of increase (λ)	Antilog e^{rm}	1.20081
7	Weekly multiplication rate	$(\lambda)^7$	3.60014
8	Corrected generation time (T)	Log eR_0 / r_m	29.24 days
9	Doubling time	Log e^2 / r_m	4.7463 days

DISCUSSION

The present study is an attempt to construct a life table of natural populations of rice leaf folder in India, to delineate and quantify the role of various mortality factors. Greenhouse studies following the fate of a cohort from birth to death revealed that only 75 per cent of the leaf folder population entered into the next generation (Table 1). There was no difference in the mortality across the seasons under greenhouse conditions. In a similar greenhouse study, Chitra *et al.* (2003) also reported that in *C.*

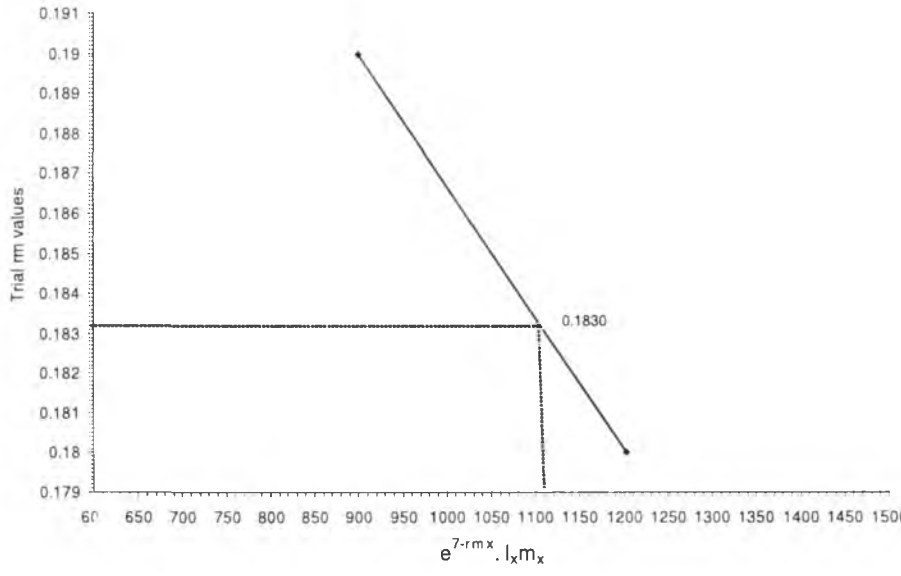

FIGURE 3. Determination of intrinsic rate of increase (r_m) of rice leaf folder.

medinalis, only 73 per cent reached adulthood whereas 65 per cent reached adulthood in *M. patnalis*. Natural population data under field conditions revealed that a number of biotic and other factors were found causing mortality of rice leaf folder at different stages. Total generation mortality (*K*) was high in *Dry* season as compared to *Wet* season (Table 2) and 28% of population in *Dry* and 48% in *Wet* survived. Mortality due to biotic factors was more in *Dry season* (34.06%) as compared to *Wet season* (29.72%). Pupal and late larval parasitoids viz., *Brachymeria* sp., *X. flavolineata* and *M. philippinensis* were the key mortality factors in both the seasons in both the years (Fig. 2). These findings were in corroboration with Pathummal Beevi *et al.* (2001) who reported 15 to 44% pupal parasitism by *Brachymeria tibialis*, *B. excarinata* and *Tetrastichus* sp and 27.2% larval parasitism by *Cardiochiles philippinensis*. Manisegaran *et al.* (1997) recorded natural parasitism of leaf folder and reported 12.81% parasitism by *A. angustibasis*, 14.87% by *Brachymeria* sp., 15.42% by *Elasmus johnstoni* and 22.42% by *Goniozus* sp. Similarly Kraker *et al.* (1999b) recorded 14 to 56% larval parasitism of leaf folders in irrigated rice in Philippines and the braconid *M. philippinensis* was the most commonly found larval parasitoid. Matsumara (1992) reported larval parasitism by *Apanteles baoris* and *Pediobius mitsukurii* as important mortality factor in the life tables of the migrant skipper, *Parnara guttata guttata* in rice. Parasitisation of various stages and failure of neonate larvae to enter the midribs were the key mortality factors reported in the life tables of sugarcane top borer, *Scirpophaga excerptalis* (Mukunthan, 1989). Similarly, life table studies on the soybean leaf folder, *Nacoleia* sp. revealed that maximum mortality (17–18%) was due to pupal parasitoids (Thakur and Gangwar, 1989).

Survivorship curves for *C. medinalis* indicated higher mortality in early stages of the life cycle under greenhouse conditions, designated as Type IV category (Slobodkin, 1962) whereas mortality was high in late stages of the life cycle under field conditions indicating Type-I category (Fig. 1).

In the present study there was no mortality in egg stage due to parasitism or predation but non-hatching of eggs contributed up to 15.3 to 17.97% mortality. However, Kraker *et al.* (1999a) reported that the egg disappearance was the major mortality factor and the average disappearance of exposed laboratory laid eggs was 40% while that of field-laid eggs was 46%. Egg mortality due to parasitism ranged between 15–18% whereas non-hatching of eggs was of minor importance. The white muscardine fungus, *Beauveria bassiana* was found causing late larval mortality in the present study (Fig. 2). Similarly, Ambethgar (1997) recorded 13–100% mycoses in larval populations due to white muscardine fungus.

Predators recorded include *Paederus* sp. (staphylinid), *Ophionea* sp. (carabid), and, *Tetragnatha* sp (spider). Earlier Rai *et al.* (2000) reported *Paederus fuscipes* as an active predator with a feeding potential of 0.6 rice leaf folder larvae per individual per day. Pathummal Beevi *et al.* (2001) reported that out of 35 predators recorded *Ophionea nigrofasiate, Nabis capsiformis* and *Paederus fuscipes* are important. The net reproductive rate (R_o) was 210.77. The approximate generation time (T_c) was 29.3 days leading to 'r_c' value of 0.1826 which revealed the capacity for increase of females/female/day. The intrinsic rate of increase r_m was derived as 0.1830 (Table 4 and Fig. 3). The capacity for increase was slightly less than intrinsic rate of increase indicating population tending towards overlapping generations.

A significant negative correlation was observed between maximum temperature, minimum temperature, rainfall, sunshine hours and leaf folder larval population whereas positive relationship was found between relative humidity (morning and evening) and larval population. Similar relationships were observed by Balasubramanian and Balasubramanian (1985) between leaf folder damage and weather factors. They also indicated that increase in maximum temperature by 1 °C may reduce the leaf folder damage by 1.75 with R^2 value of 0.445.

The life table data, presented here, revealed that the population of rice leaf folder is governed by a number of factors. Mortality was maximum in dry season as compared to wet season. Highest mortality was due to pupal and larval parasitism. Other mortality factors include blackening of pupae due to unknown reason, larval dispersal and diseased larvae. The short doubling time and high intrinsic rate of increase indicated that the leaf folder has a potential to become a serious pest but for the various biotic factors that regulate the population. But if the fragile factors are tinkered of insecticide intervention, the pest may flare up. Thus it is evident that biotic factors play a major role in the population dynamics and conservation of late larval and pupal parasitoids in the field is crucial for efficient management of this pest in rice.

ACKNOWLEDGEMENTS

We would like to thank the Project Director, Directorate of Rice Research, Hyderabad for providing necessary facilities and Dr. Debjani Dey, Senior Scientist, Division of Entomology, Indian Agricultural Research Institute, New Delhi for the identification of parasitoids.

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(Received 26 November 2007; accepted 15 February 2008)

ENTOMON **33(1)**: 15–23 (2008)
Article No. ent.33102

Records of aphids and aphidocolous ants (Hymenoptera: Formicidae) from Karnataka

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ABSTRACT: A total 66 aphid species under 38 genera belonging to seven subfamilies were recorded in Karnataka in an intensive survey for aphids during 2000–2003. The subfamily Chaitophorinae was recorded for the first time from south India. Eighteen species are recorded for the first time from Karnataka, of which six species are new records from south India. Eleven species of ants belonging to eight genera were found associated with 24 species of aphids infesting 42 host plants. The ants belonged to the subfamilies Formicinae (five species), Myrmicinae (four species) and Dolichoderinae (two species). The genera *Camponotus*, *Crematogaster* and *Monomorium* were more abundant with two species under each genus. *Camponotus compressus* Fabricius was the most common species, attending 15 species of aphids. This was followed by *Monomorium* sp. and *Solenopsis geminata* Fabricius, which attended nine and eight species of aphids, respectively. *Camponotus rufoglaucus* Jerdon, *Crematogaster soror* Forel and *Oecophylla smaragdina* Smith attended three aphid species each. This study records 26 new aphid and ant associations.

KEYWORDS: Aphids, host plants, aphidocolous ants

INTRODUCTION

In south India, aphid studies started in 1930s and were continued up to 1974, when several species were recorded from Tamil Nadu and a few from Karnataka (Ghosh, 1986). Earlier the aphid fauna of Karnataka was studied by Krishnamurti (1928, 1930, 1950) and Gadiyappanavar (1970). Numerous surveys, across the different seasons were conducted during 2000–2003 in various regions of the state. The areas surveyed for aphids includes rural and urban Bangalore, Belgaum, Chikmaglur, Dakshin Kannada, Dharwad, Hassan, Kolar, Kodagu, Mandya, Mysore and Tumkur.

The presence of ants in the aphid colony helps to increase the aphid population in three different ways. While attending the aphids for honeydew, the ants directly accelerate the aphid's growth and reproduction rate (El-Ziady, 1960). The ants

indirectly increase the reproduction rate by prolonging the aphids stay on young plant tissue where they reproduce faster than older tissues (Banks, 1958). The ants drive away the aphid natural enemies and thus allow the aphid population to increase (Flanders, 1951).

The ant–aphid association has attracted greater attention from the European workers, with the result, most of the literature available on this subject refers to the European aphid species. Various ecological (Curtright, 1965; Skinner and Whittaker, 1981), physiological (Broadbent, 1951) and ethological (Banks, 1958; Banks and Nixon, 1958; Way, 1963; Banks and Macaulay, 1967; Addicott, 1978) studies on aphid ant mutualism have been made from European countries.

Accounts of aphidocolous ants are available from Orissa (Roy and Behura, 1980), Assam, Meghalaya, Rajasthan (Kurl and Misra, 1980), West Bengal, Sikkim (Datta *et al.*, 1982, 1983; Datta and Raychaudhuri, 1984, 1985), Manipur (Devi and Singh, 1986a,b; Devi *et al.*, 1987; Shantibala *et al.*, 1995; Devi *et al.*, 2001), Jammu and Kashmir (Matta and Bhagat, 2000) and Uttranchal (Bisht *et al.*, 2002).

In southern parts of India Gadiyappanavar (1970) and Musthak Ali and Sharatchandra (1986) studied the role of establishment of root aphid on finger millet through ant association. Veeresh and Musthak Ali (1990) gave a list of aphidocolous ants from south India. In Bangalore, Karnataka, Verghese and Tandon (1987) studied interspecific association of *Aphis gossypii* Glover, *Cheilomenes sexmaculata* (Fabricius) and *Camponotus comprassus* Fabricius in guava ecosystem. No attempt has so far been made from south India to study fauna of aphidocolous ants and hence efforts were made to collect and identify aphidocolous ants from Karnataka.

MATERIALS AND METHODS

Collection and preservation of aphids

Regular surveys were made to collect aphids and associated ants on various host plants including cultivated crops, ornamental plants, trees and weeds in different districts of Karnataka State *viz.*, Bangalore Rural, Bangalore Urban, Belgaum, Chikmaglur, Dakshin Kannada, Dharwad, Hassan, Kolar, Kodagu, Mandya, Mysore, Tumkur, Bidar and Gulbarga during 2000–2003. Aphids were collected either directly from the plants with the help of camel hair brush or the alate aphids were trapped in yellow pan water traps. Sometimes, the infested plant parts along with aphid colony were collected in small plastic containers or polythene bags. The aphids thus collected were preserved in 70% ethanol in tightly stoppered small plastic vials. For microscopic studies the aphids were processed following the method proposed by van Emden (1972).

Systematics and identification of aphlid species

The aphids recorded in the present study were grouped in one of the nine subfamilies Aphididae viz., Eriosomatinae (Pemphiginae), Hormaphidinae, Anoeciinae, Chaitophorinae, Drepanosiphinae, Greenideinae, Aphidinae, Phloemyzinae and

Lachninae. The classification proposed by Remaudière and Remaudière (1977) with subfamily names used by Nieto Nafria *et al.* (1998) are followed in the study.

The aphids were identified with the help of keys provided by Eastop (1966), Raychaudhuri (1980) and Martin (1983).

The infested plant parts along with aphid colony and associated ants were collected in small plastic containers (12 × 7 cm) or polyethylene bags. The plant parts were kept in an acrylic sheet cage (30 × 30 × 30 cm) after bringing them to the laboratory. The ants were separated from aphid colony and preserved in 70% ethyl alcohol in small plastic vials (2.5 ml). Each vial was furnished with data on locality, host plant, date and collector's name on thin paper.

RESULTS AND DISCUSSION

A total of 66 aphid species under 38 genera belonging to seven subfamilies were recorded from Karnataka in the present study (Table 1). Krishnamurti (1928, 1930, 1950) and Gadiyappanavar (1970) recorded 20 and 30 aphid species from Karnataka, respectively. Gadiyappanavar (1970) also provided a list of 67 host plants of various aphid species.

The subfamily Chaitophorinae was recorded for the first time from south India, however, the subfamilies Phloemyzinae and Anoeciinae could not be recorded. In earlier studies also species belonging to these subfamilies were not recorded. Family Aphidinae was the most dominant group with 65.15% of the total species recorded. Subfamily Greenideinae and Hormophidinae were second and third in dominance, respectively, having 12.12 and 9.09% of the total species recorded.

Out of 66 aphid species recorded in the present study, 24 species were attended by 11 species of ants belonging to eight genera on 42 species of host plants (Table 2). The ants belonged to the subfamilies Formicinae (five species), Myrmicinae (four species) and Dolichoderinae (two species). The genera *Camponotus*, *Crematogaster* and *Monomorium* were more common with two species each. *Camponotus compressus* Fabricius was the most common, attending 16 species of aphids. This was followed by *Monomorium* sp. and *Solenopsis geminata* Fabricius, which attended nine and eight species of aphids, respectively. *Camponotus rufoglaucus* Jerdon, *Crematogaster soror* Forel and *Oecophylla smaragdina* Smith attended three aphid species each.

Aphis craccivora Koch and *A. spiraecola* Patch were attended by five species of ants, while *Rhopalosiphum maidis* (Fitch), *A. gossypii* and *Toxoptera odinae* (van der Goot) were attended by four species. *Hysteroneura setariae* (Thomas) and *T. aurantii* (Boyer de Fonscolombe) were attended by three species of ants and *T. citricida* (Kirkaldy), *Tetraneura nigriabdominalis* (Sasaki) and *Greenidea ficicola* Takahashi were attended by two ant species each. Of the 24 species of aphids attended by ants, majority of the species belonged to the genus *Aphis* (five), followed by *Toxoptera* (three) and *Greenidea* (two). *Oecophylla smaragdina* Smith attended aphids infesting citrus and mango, interestingly this species of ant is also considered as a pest on these host plants.

TABLE 1. List of aphid species recorded from Karnataka during the study

Subfamily	Tribe	Species
Aphidinae	Aphidini	*Aphis achyranthi* Theobald[††]
		Aphis craccivora Koch
		Aphis fabae Theobald
		Aphis glycines Matsumura[†]
		Aphis gossypii Glover
		Aphis nerii (Boyer de Fonscolombe)
		Aphis punicae Passerini
		Aphis spiraecola Patch
		Hyalopterus pruni (Geoffroy)[††]
		Hysteroneura setariae (Thomas)
		Melanaphis donacis (Passerini)
		Melanaphis sacchari (Zehntner)
		Rhopalosiphum maidis (Fitch)
		Rhopalosiphum nymphaeae (L.)
		Rhopalosiphum padi (Linn.)[††]
		Rhopalosiphum rufiabdominalis (Sasaki)
		Schzaphis rotundiventris (Signoret)[††]
		Schizaphis graminum-(Rondani)
		Toxoptera aurantii (B. d. Fonsc.)
		Toxoptera citricida (Kirkaldy)
		Toxoptera citricida (Kirkaldy)
	Macrosiphini	*Acyrthosiphon gossypii* Mordvilko[††]
		Acyrthosiphon kondoi Shinji & Kondo
		Acyrthosiphon pisum (Harris)
		Brachycaudus helichrysi (Kalt.)
		Brevicoryne brassicae (Linn.)
		Capitophorus elaeagni (del Guercio)
		Coloradoa rufomaculata (Wilson)
		Hayhurstia atriplicis (Linnaeus)[††]
		Hydaphis coriandri (Das)
		Hyperomyzus carduellinus (Theobald)[††]
		Ipuka dispersum (van der Goot)[††]
		Macrosiphoniella sanborni (Gill.)
		Macrosiphum rosae (Linn.)
		Myzus persicae (Sulzer)
		Pentalonia nigronervosa Coquerel
		Sitobion leelamaniae David
		Sitobion rosaeiformis (Das)
		Sitobion takahashii Eastop
		Uroleucon (Uromelan) compositae (Theobald)
		Uroleucon (Uroleucon) sonchi (Linnaeus)

Contd...

TABLE 1. (Contd..)

Subfamily	Tribe	Species
Chaitophorinae		*Chaitophorus himalayensis* (Das)†
Drepanosiphinae		*Therioaphis trifolii* (Monell)
		Unipterus (*Paoliella*) *nirmalae* David
		Tinocallis kahawaluokalani (Kirkaldi)††
Greenideinae	Cervaphidini	*Cervaphis rappardi indica* Basu
		Schoutedenia emblica (Patel & Kulkarni)
	Greenideini	*Greenidea* (Greenidea) *artocarpi* (Westwood)
		Greenidea (*Greenidea*) *ficicola* Takahashi
		Greenidea (*Trichosiphum*) *annonae* (Pergande)††
		Greenidea (*Trichosiphum*) *formosana heeri* Raychaudhuri, Ghosh, Banerjee and Ghosh††
Hormaphidinae	Cerataphidini	*Astegopteryx bambucifoliae* (Takahashi)
		Astegopteryx bambusae (Buckton)
		Astegopteryx formosana (Takahashi)
		Cerataphis brasiliensis (Hempel)†
		Cerataphis lataniae (Boisduval)
		Cerataphis orchidearum (Westwood)††
		Ceratovacuna lanigera Zehntner
		Pseudoregma bambusicola (Takahashi)
Lachninae	Cinarini	*Cinara tujafilina* (Del Guercio)†
	Lachnini	*Tuberolachnus salignus* Gmelin†
Pemphiginae	Eriosomatini	*Forda orientalis* George
		Tetraneura (*Tetraneurella*) *nigriabdominalis* (Sasaki)
		Tetraneura (*Tetraneurella*) *javensis* Goot††

††First record from Karnataka
†First record from south India

Earlier workers from south India indicated only presence or absence of ant attendance without mentioning the ant species involved with the exception of Gadiyappanavar (1970) who recorded *C. comprressus* and *S. geminata* attending *T. nigriabdominalis*. Same species of ants were found to attend *T. nigriabdominalis* in the present study. In addition to this Musthak Ali and Sharatchandra (1986) and Veeresh and Musthak Ali (1990) have enlisted aphidocolous ants from southern India. More studies on aphid and ant relationship are available from northern and northeastern parts of India as compared to southern parts of India.

Twenty-four new aphid-ant associations (marked by an asterisk in second column of Table 2) were recorded in the present study. Studies thus indicated that the area of survey is rich in aphid as well as ant species attending to them.

TABLE 2. Aphidocolous ants (Hymenoptera: Formicidae) collected from Karnataka

Ant subfamily & species	Associated aphid species	Host plant
Formicinae		
Camponotus comprassus Fabricius	*Aphis craccivora* Koch	*Cajanus cajan* (Linn.)
		Crotolaria juncea Linn.
		Crotolaria mucronata Desvaux
		Dolichos lablab Linn.
		Gliricidia maculata (Jacq.) Kunth ex Walp.
		Mimosa pudica Mill.
		Vigna unguiculata (Linn) Walp.
	Aphis fabae Theobald	*Cestrum nocturnum* Linn.
		Solanum nigrum Linn.
	Aphis gossypii Glover	*Solanum melongena* Linn.
		Solanum sp.
		Gossypium hirsutum Linn
		Hibiscus rosa-sinensis Linn.
	Aphis spiraecola Patch *	*Chromolaena odorata* (Linn.) King & Robs
	Cinara tujafilina (Del guercio)	*Thuja chilensis* Borders and Gaussen
	Greenidea ficicola Takahashi *	*Ficus tsiela* Roxb
	Hysteroneura setariae (Thomas)	*Cyperus rotundus* Miq.
		Chlorophytum sp.
		Eleusine coracana (Linn.) Gaertn.
	Melanaphis sacchari (Zehnter)	*Sorghum bicolor*(Linn.) Moench.
	Rhopalosiphum maidis (Fitch)	*Zea mays* Linn.
	Schoutedenia emblica (Patel & Kulkarni) *	*Phyllanthus emblica* Linn.
	Sitobion takahashii Eastop *	*Phyllanthus emblica* Linn.
	Tetraneura nigiabdominalis (Sasaki)	*Eleusine coracana* (Linn.) Gaertn.
	Toxoptera aurantii(B.d.F.)	*Ixora* sp.
		Camelia theifera Griff
	Toxoptera citricida (Kirkaldy)	*Citrus* sp.
	Toxoptera odinae (van der Goot)	*Anacaardium occidentale* Linn.
	Ceratovacuna lanigera Zehntner	*Saccharum officinarum* Salisb.
Camponotus rufoglaucus Jerd.	*Aphis craccivora* Koch	*Sesbania grandiflora* (Linn.) Pers
	Aphis fabae Theobald	*Cerstrum nocturnum* Linn.
		Solanum nigrum Linn.
Crematogaster ransonneti Mayr	*Tuberolachnus salignus* (Gmelin) *	*Salix* sp.
Crematogaster soror Forel.	*Aphis craccivora* Koch *	*Arachis hypogaea* Willd.
	Aphis gossypii Glover*	*Solanum melongena* Linn.
	Aphis spiraecola Patch*	*Chromolaena odorata* (Linn.) King & Robs.

Contd..

TABLE 2. (Contd...)

Ant subfamily & species	Associated aphid species	Host plant
Oecophylla smaragdina Smith	*Chaitophorus himalayensis* (Das)*	*Salix* sp.
	Toxoptera aurantii (B.d.F.)	*Ixora* sp. *Citrus* sp.
	Toxoptera odinae (van der Goot)*	*Hibiscus rosa-sinensis* Linn. *Mangifera indica* Linn.
Myrmicinae		
Monomorium gracillium Smith	*Unipterus nirmalae* David *	*Terminalia arjuna* (Roxb.ex DC.) Wight & Arn.
Monomorium sp.	*Aphis affinis* Del Guercio *	*Mentha viridis* (Linn.)
	Aphis craccivora Koch	*Vigna unguiculata* (Linn.) Walp.
	Aphis gossypii Glover	*Gossypium hirsutum* Linn.
	Aphis spiraecola Patch	*Chromolaena odorata* (Linn.) King & Robs.
	Rhopalosiphum maidis (Fitch)	*Zea mays* Linn.
	Toxoptera aurantii (B.d.F.) *	*Camelia theifera* Griff
	Toxoptera odinae (van der Goot) *	*Anacardium occidentale* Linn. *Hibiscus rosa-sinensis* Linn. *Ixora* sp.
	Greenidea (Trichosiphum) formosana heeri Raychaudhuri *et al.**	*Psidium guajava* Linn.
	Dactynotus sonchi Linnaeus	*Sonchus arvensis* Linn.
Myrmicaria brunnea Saunders	*Rhopalosiphum maidis*(Fitch) *	*Zea mays* Linn.
Solenopsis geminata Fabricius	*Aphis craccivora* Koch	*Vigna unguiculata* (Linn.) Walp. *Dolichos lablab* Linn. *Gliricidia maculata* (Jacq.) Kunth ex Walp.
	Aphis nerii (B.d.F.) *	*Asclepias curassavica* Griseb. *Asclepias physocarpa* Schlechter
	Aphis spiraecola Patch *	*Chromolaena odorata* (Linn.) King & Robs.
	Pentalonia nigrinervosa Coquerel	*Musa sapientum* Linn. *Alpinia versicolor* K.Schum. *Maranta zebrina* Sims
	Rhopalosiphum maidis (Fitch) *	*Zea mays* Linn.
	Hysteroneura setariaei (Thomas) *	*Eleusine coracana* (Linn.) Gaertn.
	Tetraneura nigiabdominalis(Sasaki)	*Eleusine coracana* (Linn.) Gaertn.
	Toxoptera citricida (Kirkaldy) *	*Citrus* sp.
Dolichoderinae		
Tapinoma melanocephalum Fabricius	*Aphis spiraecola* Patch *	*Chromolaena odorata*(Linn.) King & Robs.
	Hysteroneura setariae (Thomas) *	*Eleusine coracana* (Linn.) Gaertn.
Technomyrmex albipes Smith	*Aphis gossypii* Glover *	*Hibiscus rosa-sinensis* Linn.
	Toxoptera odinae (van de goot) *	*Hibiscus rosa-sinensis* Linn.

*New aphid ant associations

ACKNOWLEDGEMENTS

I am indebted to Dr. C. A. Viraktamath, Scientist Emeritus, University of Agricultural Sciences, GKVK, Bangalore for guidance, technical support and comments on the paper. I am thankful to Prof. T. M. Musthak Ali, Professor, Department of Entomology, UAS, GKVK, Bangalore for identification of ant species. The study leave granted to me y the Project Director, Project Directorate of Biological Control (ICAR), Hebbal, Bangalore, is gratefully acknowledged.

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(Received 21 December 2007; accepted 15 February 2008)

ENTOMON 33(1): 25–34 (2008)
Article No. ent.33103

Voltage gated potassium channels in the larval CNS neurons of coconut black headed caterpillar, *Opisina arenosella* Wlk.

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ABSTRACT: A primary dissociated cell culture of *Opisina arenosella* Wlk. larval Central Nervous System (CNS) neurons was established. The acutely dissociated larval CNS neurons could be divided into two categories based on their morphology and size. Type I consisted of rounded cells and type II consisted of cells with processes. Nearly 60 per cent of the cells were alive after 7 days of plating. Whole cell currents were recorded from Type II cells (5–12 μm) of 12–48 h using the patch clamp setup. The outward potassium currents were obtained from the neuronal cells. The absence of potassium currents from the cells when exposed to potassium channel blockers (cocktail of 4-aminopyridine (1 mM), quinidine (0.1 mM) and tetraethylammonium (TEA, 20 mM) in extra cellular bath) confirmed the potassium currents. Three types of potassium currents (non inactivating, slow inactivating, and fast inactivating currents) were observed in whole cell recording of Type II cells.

KEYWORDS: *Opisina arenosella*, cell culture, patch clamp, potassium currents

INTRODUCTION

Neuronal signaling depends on rapid change in the electrical potential differences across nerve cell membranes. Insect neuronal cell membranes have a variety of distinct potassium channels that can be activated by changes in membrane voltage (Latorre *et al.*, 1984). The relative number and spatial distribution of these channels in the cell determine the particular excitability properties of the neuron (Adams *et al.*, 1980; Thompson and Aldrich, 1980). The information about voltage-dependant ion channels (VDIC) have been investigated using cultured neurons of *Drosophila melanogaster* (Wu and Suzuki, 1983; Subaharan, 2004) and other insects (Hayashi and Hildebrand, 1990). Ion channels are primary target site for several classes of

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natural and synthetic insecticide compounds (Okuma and Yoshiyuki, 2004). Potent natural toxins like apamin, and dendrotoxin and ecdysteroid agonist RH-5849 block the potassium channels (Castle *et al.*, 1989; Salgado, 1992a,b).

The coconut black headed caterpillar, *Opisina arenosella* Wlk. is a serious pest on coconut (Singh and Rethinam, 2006). The larvae feed on the parenchymatous tissues on the undersurface of the coconut leaflets and constructs galleries of silk and excreta (Nirula *et al.*, 1951). This pest occurs in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal, Maharashtra and Gujarat states of India (Venkatesan *et al.*, 2003). Though the innundative release of parasitoids keeps the population of the pest under check their timely availability for release during the outbreak is a limiting factor. Hence, during the outbreak it warrants the use of pesticides to check the spread of pest to newer locations. Currently farmers resort to spraying of malathion, dichlorvos (Ponnama, 1984) and stem injection or root feeding of monocrotophos (Shivakumar, 1999; Patalappa, 1988). As monocrotophos and dichlorvos have been brought under the restricted use pesticide status, there is a need to search for insecticides with novel chemistry that can be harmoniously used in integrated management of this pest. During the process of screening of newer molecules bioassay coupled with electrophysiology studies would furnish additional information at cellular level on the potency of neurotoxic insecticides. This study can be facilitated by establishing dissociated neuronal cultures of the test insect and then studying its channel properties. Examining the K^+ channels in *O. arenosella* neuronal membrane by biophysical methods would provide a powerful approach for studying the channel properties.

No earlier attempts have been made to culture CNS neurons from *O. arenosella* larvae. As *in vitro* cell culture allows continuous observation on isolated cells, an attempt was made to establish a primary culture of dissociated neurons of CNS of seventh instar *O. arenosella* larval brain. The suitability of dissociated CNS cell culture of *Drosophila melanogaster* for patch clamp analysis has been suggested (Sun and Wu, 1984, Solc and Aldrich, 1988, Yamamoto and Suzuki, 1987). Hence, in the present study we attempted to develop a dissociated CNS neuronal cell culture of *O. arenosella* and characterize the voltage dependent K channels at the whole cell level by patch clamp technique.

MATERIALS AND METHODS

Insect culture

The larvae of *O. arenosella* were collected from the Tiptur tall palms in Tumkur block of Karnataka State in India. The insects were reared in the laboratory in a glass jar provided with fresh coconut leaves, following the method of Santhosh Babu and Prabhu (1987).

Cell culture

To obtain the CNS neurons, uniform size seventh instar *O. arenosella* larvae were taken and rinsed in double distilled water twice followed by a rinse in 70 % ethanol for 1–2 min. They were again rinsed in double distilled water to remove the traces of alcohol. The larval brain was dissected using micro forceps in phosphate buffer saline (PBS) and was immediately transferred to another dish containing PBS to prevent the contamination due to regurgitated material by the larvae while dissecting. The brain was then mechanically teased in PBS and then incubated in Ca^{2+} and Mg^{2+} free PBS containing 0.5 mg/ml collagenase (Type I Sigma) saline for one hour in an eppendorf tube in sterile condition. After incubation the contents in the tube were triturated 50 times with a pipette tip. The preparation was centrifuged for 1–2 min at 3000 rpm. The supernatant was discarded. The pellet was re-suspended in Grace insect medium (Sigma) supplemented with 1.5% penicillin/streptomycin (Sigma) and 10 % Fetal Bovine Serum (Gibco). The cell suspension was plated on autoclaved cover slips at a density of one brain complex / cover slip. The cover slips were coated with Poly L Lysine (Sigma). The cover slips were then placed in a sterile 35 mm Petri dish (Tarsons) and incubated at 19 –22 °C in a humidified incubator. The cell types were also studied based on the morphology.

In order to assess the viability of CNS neurons, the cell culture was observed at varied intervals (1, 2, 4, 6, 8 and 10 days after plating) under an inverted phase contrast microscope (Nikon–Diaphot 200). Each time destructive sampling was done using Tyrosine blue stain as indicator. The per cent mortality of cells at varied intervals was worked out.

Electrophysiology

Membrane currents of neurons were studied in order to characterize the type of channels present in the CNS neurons. Recordings were made from 2–6 days old dissociated CNS neurons cell culture having 5–12 μm long processes. Currents were recorded using the whole-cell configuration of the patch-clamp technique using an Axopatch amplifier (Axon instruments). The patch-clamp electrodes with a resistance of 2–8 MΩ were fabricated from borosilicate glass with a Narishige PP-83 puller. The capillaries were polished with Narishigae microforge. The patch pipettes of around 1 μm diameter were filled with internal solution.

Whole cell currents were recorded from 2, 4 and 6 day old bipolar neurons (5–12 μm), using the patch clamp setup (Axon instruments). In external bath solution, a typical electrode resistance of around 2–8 MΩ was obtained. The seal was made by a brief suction at the cell surface after the electrode touched the cell. A tight seal was immediately formed and a typical resistance of around 1–50 GΩ was obtained. The capacitive transients were minimized. A whole cell configuration was attained by a few light suctions. Increase in the size of capacitive transients and a little fall in the seal resistance confirmed whole cell configuration. Capacitive transients were compensated at this stage. The cells were voltage clamped at −100 mV and

an increasing step of 20mV was given each time (i.e. −80 mV, −60 mV, −40 mV, −20 mV, 0 mV, 20 mV, 40 mV, 60 mV, and 80 mV) for 200 ms interval.

The recordings were acquired and analyzed using *pClamp6.0* software (Axon Instruments) run on an IBM compatible '386' computer. Currents recorded from cells were filtered online using 1000 Hz frequency filter. After acquisition, the baseline of the currents was compensated and the leak subtracted. Amplitude of the peak currents obtained in the cultures was measured.

RESULTS

Dissociated neurons of *Opisina arenosella* CNS in primary cell cultures

After plating, the dissociated CNS neuronal cells settled down and got attached to the poly-lysine coated dishes within 3 h of plating. The cells, which do not adhere to the dish, remain rounded and died out. There were no glial cells in the culture.

The acutely dissociated larval CNS neurons could be divided into two categories based on their morphology and size. Type I consisted of rounded cells (diameter $> 5\ \mu$m) with no process and they comprised approximately 30% of the population. Type II cells comprised approximately 70% of the total population. In addition to soma they had (5–7μm) processes (Fig. 1).

Viability of CNS neuronal cells in culture

Viability of the cells was measured as a function of days using hemocytometer. Trypan blue permeable cells were counted as dead. More than 60% of the cells were alive 6 days after plating (Table 1).

Heterogeneity of whole cell currents

The acutely dissociated CNS neuronal type I cells were not suitable for forming a giga ohm seal during whole cell recording. Hence, the type II cells, which comprised the largest population of dissociated CNS neuronal cells, were selected for the study of membrane currents.

The currents obtained in all the larval CNS neurons clamped exhibited only net outward currents in response to depolarizing step pulses (−80, −60, −40, −20, 0, 20, 40, 60, 80 mv). The outward currents were similar to potassium currents. A cocktail of 4-aminopyridine (1 mM), Quinidine (0.1 mM) and tetraethylammonium (TEA, 20 mM) was used in extra cellular bath to block all the currents passing through potassium channels as suggested by Deepti (2002). No currents were observed in the presence of these blockers. This confirmed that the outward currents were potassium channel specific. Also, in absence of potassium currents no other type of currents could be observed in cells in culture. The current/voltage relationship was measured for the various depolarizing voltage commands.

Heterogeneity of the whole cell outward currents in peak amplitude and inactivation time constants existed. The classification of K+ currents was the first step towards

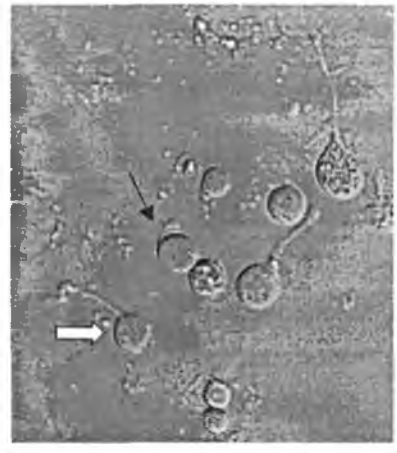

FIGURE 1. Dissociated *O. arenosella* larval CNS neuronal cell culture. Black arrow shows the Type I spherical cells and white open arrow shows the Type II cells with processes.

TABLE 1. Viability of neuronal cells

Age of the neuronal cells (days)	Per cent mortality ±SE
1	92.2 ± 1.06^{a}
2	90.2 ± 0.58^{ab}
4	86.8 ± 1.15^{b}
6	63.6 ± 2.73^{c}
8	53.4 ± 2.80^{c}
10	37.6 ± 2.50^{c}

Means with same letter are not significantly different at $p = 0.05$ with DnMRT.

detecting an alteration in K+ currents. Three kinds of outward K+ currents were observed. This classification was according to their fast inactivation time constants. All the three types of currents were voltage dependent and their I/V curves were similar (Fig. 2—4). Some cells exhibited primarily a fast transient K current that turned on and inactivated rapidly in response to depolarizing voltage steps whilst some neurons had K currents with slower inactivation time course. A group of cells also expressed a non inactivating component of outward current.

Types of potassium currents

Three kinds of voltage sensitive potassium currents were distinguishable. These were classified on the basis of their activation and inactivation kinetics.

Non inactivating type

No inactivation of the channels were observed in 200 ms. Peak current was obtained after 80.80 ± 1.40 ms of the beginning of the voltage step. The activation of K1

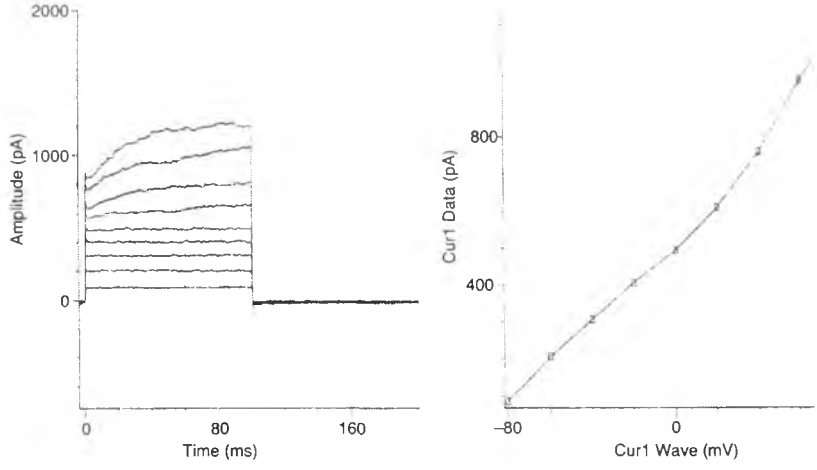

FIGURE 2. Non inactivating type currents: The traces here show the −80, −60, −40, −20, 0, 20, 40, 60, 80 mv pulses after the baseline correction and leak subtraction. The plot of current vs voltage is on the right.

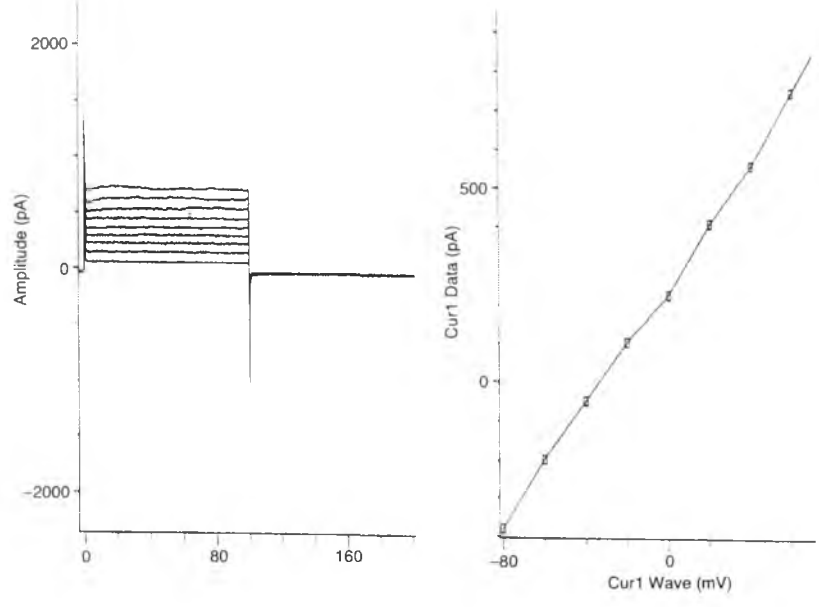

FIGURE 3. Slow inactivating currents. The traces here show the −80, −60, −40, −20, 0, 20, 40, 60, 80 mv pulses after the baseline correction and leak subtraction. The plot of current vs voltage is on the right.

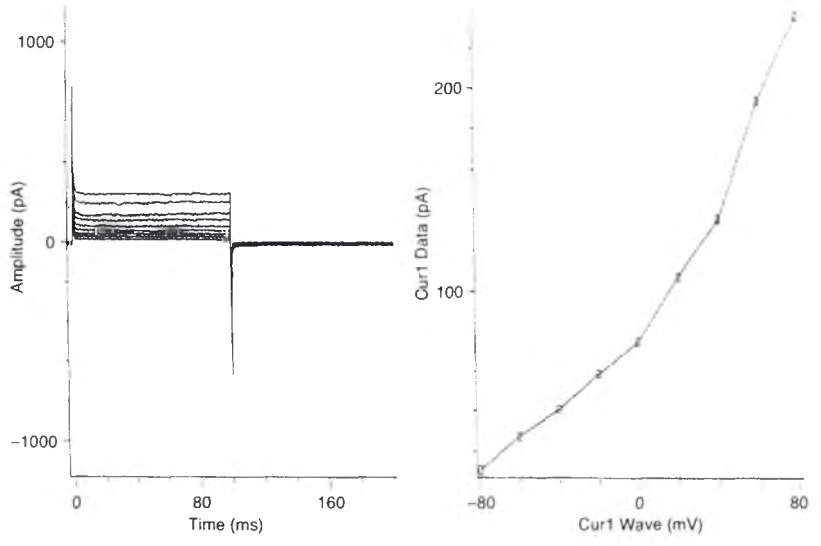

FIGURE 4. A fast inactivating current. The traces here show the −80, −60, −40, −20, 0, 20, 40, 60, 80 mv pulses after baseline correction and leak subtraction. The plot of current vs voltage is on the right.

TABLE 2. Types of K+ currents in neuronal culture

Days after plating	Number of cells showing (currents)		
	Fast inactivating	Slow inactivating	Non inactivating
2	60.00	10.00	30.00
4	58.13	11.62	30.23
6	55.55	16.66	27.77

channels followed first order exponential kinetics with time constant of activation 20.48 ± 1.6 ms (Fig. 2).

Slow inactivating type

These channels activate faster than K1 channels with peak current at 26.80 ± 2.0 ms. The inactivation kinetics is slow and follows a single exponential function of inactivation (Fig. 3).

Fast inactivating type

These are fast inactivation type channels. The activation of these channels after the voltage pulse beginning was very fast and the peak current reached at around 12.2 to 4.77 ms. The inactivation was also very fast. Two time constant might reflect the intrinsic property of these channels (Fig. 4).

Analysis of the decay phase of the currents recorded from larval CNS neurons of *O. arenosella* showed the following distribution. Irrespective of the age majority of the cells showed the fast transient currents followed by non inactivating or sustained currents. A minority of the neurons exhibited primarily a delayed transient K+ currents (Table 2). There was not much difference in the type of potassium currents with increase in age of the cells.

DISCUSSION

The primary culture of dissociated CNS neurons from VII instar *O. arenosella* larvae was established. Two types of neurons were observed in cultures. Majority of the cells had processes. In case of *D. melanogaster*, three types of cells were observed in the dissociated larval CNS culture. They were differentiated based on their size and morphology (Wu *et al.*, 1983; Subaharan, 2004). Sang (1981) reported that neuronal cultures obtained from larval brains by dissection was relatively free from glial cells. In our studies also we observed that the frequency of cells with non neuronal morphology was less than 1% in cultures of different ages. The relatively low number of glial cells in culture was not due to its inability to survive in culture medium but due to the lower number of glial cells in insect CNS.

In the dissociated CNS cell culture more than 60 per cent of the cells were viable 4 days after plating. Neuronal cultures have proved to be useful for a number of studies. The neuronal cells in the culture system aids in the study of membrane currents by electrophysiological technique (Wu *et al.*, 1983). Primary cultures have been used to record neuronal current properties owing to the easily manageable conditions in cultures as compared to *in vivo*. Primary cultures have been previously made from central nervous system of *Drosophila* (Wu *et al.*, 1983).

There have been several studies on voltage dependant current in insect neurons (Leung and Byerly, 1991; Saito and Wu, 1991; Solc and Aldrich, 1988). No studies have been done on *O. arenosella*. Hence our goal was to examine the membrane currents of the cultured CNS neuronal cells. Patch clamp recordings were done on neurons from VII instar *O. arenosella* larval CNS cultures.

Potassium currents in larval CNS neurons had three components: a fast transient component, a more slowly inactivating component and a non-inactivating component. The relative amount of each component varied from cell to cell. Solc and Aldrich (1988) reported that the *D. melanogaster* larval CNS neurons had three distinct K channels; in addition they did not observe any voltage dependent Na currents in the cells studied. Diversity of K channel provides a basis for a wide spectrum of physiological properties among the cells recorded. K currents with diverse characters play a vital role in several phenomena such as depolarization of membrane potential, repetitive firing and sensory receptor potential (Hille, 1992).

Among the types of potassium currents recorded by whole cell recording majority of the channels; exhibited fast activating type i.e A type channel. The information obtained on the potassium channel on the neuronal membranes of *O. arenosella* larvae can be used to screen novel compounds that could be effective in their

management. Insecticides (Beleaf, FMC) with novel chemistry targets on the A type potassium channel (fast activating type) of central nervous system of the insect. These insecticides cause rapid and irreversible feeding cessation in the targeted pests, ultimately resulting in starvation and death.

ACKNOWLEDGEMENTS

The first author acknowledges Prof. Obaid Siddiqi for providing the facility of electrophysiology units for the study.

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(Received 5 December 2007; accepted 15 February 2008)

ENTOMON **33(1)**: 35–40 (2008)
Article No. ent.33104

Fecundity and developmental stages of Rice Blue Beetle, *Leptispa pygmaea* Baly (Coleoptera: Chrysomelidae) on rice varieties

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ABSTRACT: Biological studies on fecundity and developmental stages of rice blue beetle, *Leptispa pygmaea* Baly (Coleoptera :Chrysomelidae) were conducted at the Regional Agricultural Research Station Pattambi, Kerala Agricultural University, under net house condition on two rice varieties viz., Jyothi (short duration) and Aiswarya (medium duration) during June to October 2005. Adult beetle laid oval shaped yellow eggs on both the leaf surfaces either singly or in parallel rows with an average fecundity of 16.8 eggs on short duration variety Jyothi and 14.3 eggs on medium duration rice variety Aiswarya. The incubation period was 3.4 days in both varieties. The grub had five larval instars each with duration of 1–2 days and completed grub development within a mean period of 8.2 days. The grub pupated on the surface of leaf by getting attached loosely at its posterior end. The pupal period was 3.2 and 2.9 days in Jyothi and Aiswarya, respectively and completed the life cycle within 14.8 in Jyothi 13.8 days in Aiswarya. The pre-oviposition period of *L. pygmaea* showed no marked difference between varieties of rice. The longevity of adult varied with the sex of blue beetle. Males lived longer than females. Adult male of *L. pygmaea* lived for 40.9 days on Jyothi and 36.7 days on Aiswarya. The male life span was longer in Jyothi than Aiswarya. The females lived for an average period of 25 days in both varieties, thus indicating a shorter life for females than males.

KEYWORDS: *Leptispa pygmaea*, rice varieties, development, fecundity

INTRODUCTION

The scenario of insect pest complex in rice has undergone a tremendous change during the pa years. Certain insect pests of relatively minor importance have started appearing as ıajor problems in rice. One among them is Rice Blue Beetle, *Leptispa pygmaea* Ba (Coleoptera: Chrysomelidae) which is becoming a serious problem in several rice ·rowing districts of Kerala. The present investigations were, therefore,

undertaken to study the biological events of the pest under Kerala conditions. The study of life cycle of a pest is essential in order to identify the susceptible life stages which provide important clues for intervention and management.

MATERIALS AND METHODS

The biological studies of *Leptispa pygmaea* were carried out in the net house at the prevailing conditions of maximum temperature (30.1°C ± 1.40°C), minimum temperature (23.1°C ± 0.69°C) and relative humidity (94.33% ± 2.11%) during June to October, 2005. The biology was studied on two rice varieties *viz.*, Jyothi (short duration) and Aiswarya (medium duration) by raising them in mud pots in the net house at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University. Adult beetles of *L. pygmaea* were collected from unsprayed rice fields and reared them on potted rice seedlings (variety Jyothi) covered with polyester cages of size 49 × 18 cm in the net house. This served as a stock culture for the steady supply of beetles required for conducting various net house studies.

A pair of freshly mated beetles of *L. pygmaea* collected from the stock culture was released on 15 days old potted rice seedlings and covered with a polyester cage of size 49 × 18 cm closed by muslin cloth at one end which served as a replication. Ten such replications were maintained on Jyothi and Aiswarya for studying the life cycle of *L. pygmaea*. Observations on the site of oviposition, pre-oviposition period, oviposition period, fecundity, incubation period and hatchability of eggs were recorded. The number of eggs laid per female was recorded daily, until the cessation of egg laying and the total number of eggs laid was worked out to obtain the fecundity. Number of larval instars, duration of each larval instar, total larval period, pupal period and total period of life cycle from egg to adult were also observed and the mean and standard deviation values were worked out. The life cycle was studied on both Jyothi and Aiswarya varieties of rice. The longevity of the beetles was recorded until death of the beetles and their mean and standard deviation values were worked out in both Jyothi and Aiswarya varieties.

RESULTS AND DISCUSSION

Site of ovipostion, fecundity and oviposition period

The female beetle of *L. pygmaea* laid either single yellow oval shaped egg (Fig. 1) or in groups of 2, 3, 4 or 5 in a straight line on the upper or lower surface of mature or tender leaves of young rice plant thus indicating no preference for surface and age of rice leaf for oviposition. In the short duration variety Jyothi, it laid a mean of 16.8 eggs (Table 1) during an oviposition period of six days.

In the medium duration variety Aiswarya, a lower fecundity of 14.3 eggs was observed. A higher fecundity was thus observed in the short duration Jyothi than the medium duration Aiswarya. Egg laying was observed to be highest on the first day and thereafter it was reduced during the last fifth and sixth day on both the varieties. Eggs were seen glued to the dorsal or ventral leaf surface and no significant difference

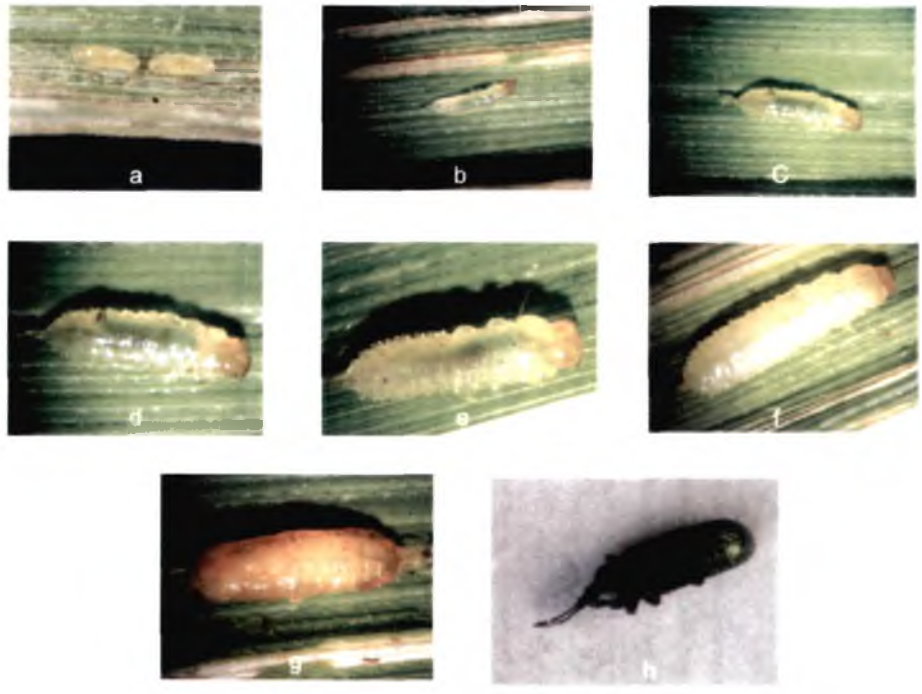

FIGURE 1. Life stages of *Leptisma pygmaea*: a, eggs; b, c, d, e and f, 1st, 2nd, 3rd, 4th and 5th instar grub; g, Pupa; h , Adult beetle.

on the site of oviposition between rice varieties was observed and the eggs turned yellowish towards hatching.

In Maharashtra, Dalvi *et al.* (1985) observed that female blue beetle laid 38–66 eggs singly or in batches of 2, 3 or 4 in a straight line mostly on the lower surface. Very rarely eggs were observed on the upper surface of the leaves. Biological studies conducted in Gujarat (Patel and Shah, 1985) indicated that *L. pygmaea* laid an average of 43 and 58.78 eggs when temperature was above 30 °C and below 30 °C respectively showing a lower fecundity when temperature was above 30 °C. Dalvi *et al.* (1985) reported a higher fecundity of 43–58.78 eggs at a temperature range of 28–29 °C. The present study showed a lower fecundity for *L. pygmaea* which might be due to the higher temperature conditions prevailing in Kerala. An oviposition period of six days was observed in the present study, whereas in Maharashtra and Gujarat it was found to be 14 days (Patel and Shah, 1985; Dalvi *et al.*, 1985).

Developmental stages

Eggs of *L. pygmaea* hatched into creamish white grubs within a mean period of 3.4 days (Table 1) in both Jyothi and Aiswarya thus indicating no difference between varieties. According to Patel and Shah (1985), the incubation period varied from 3.79

TABLE 1. Biology of *Leptispa pygmaea* on the rice varieties Jyothi and Aiswarya

Biological Parameters	Varieties of rice	
	Jyothi	Aiswarya
Mean number of eggs/Female	16.8 ± 1.23	14.3 ± 2.95
Mean egg period (Days)	3.4 ± 0.52	3.4 ± 0.52
Mean Larval period (Days)	8.2 ± 1.00	8.2 ± 0.40
Mean pupal period (Days)	3.2 ± 0.40	2.9 ± 0.57
Total life cycle (Days)	14.8 ± 2.15	13.8 ± 1.03
Pre-oviposition period (hours)	21.0 ± 4.10	20.3 ± 2.58
Adult male longevity (Days)	40.9 ± 12.17	36.7 ± 11.21
Adult female Longevity (Days)	24.9 ± 4.48	24.7 ± 3.50

± indicates SD

TABLE 2. Duration of different larval stages of *L. pygmaea* on Jyothi and Aiswarya

Stage	Paddy variety	
	Jyothi	Aiswarya
Ist instar	2.2 ± 0.13	1.8 ± 0.42
IInd instar	1.6 ± 0.52	1.9 ± 0.32
IIIrd instar	1.3 ± 0.48	1.2 ± 0.42
IVth instar	1.3 ± 0.48	1.4 ± 0.52
Vth instar	1.8 ± 0.42	1.9 ± 0.74

± indicates SD

to 7.16 days depending upon the temperature and the incubation period increased with decrease in temperature. They observed a constant level of 35 °C was lethal for hatching of eggs. The present result is in agreement with the findings of Patel and Patel (1970) who reported an incubation period of 4 to 5 days in *L. pygmaea*.

Duration of different larval instars

In both Jyothi and Aiswarya, five instars were observed (Fig. 1) during the grub stage of rice blue beetle. The mean duration of 1st, 2nd, 3rd, 4th and 5th instars were found to be 2.2, 1.6, 1.3, 1.3 and 1.8 days respectively on Jyothi and the corresponding values on Aiswarya were 1.8, 1.9, 1.2, 1.4 and 1.9 days (Table 2). The average grub period (8.2 days) of *L. pygmaea* was found to be same in both varieties. Dalvi *et al.* (1985) observed that larva of *L. pygmaea* was fully developed in 12–14 days in Maharastra. Patel and Shah (1985) also reported a higher larval period of 11.3 days for blue beetle in Gujarat. Five instars each with duration of 1–2 days were found in both Jyothi and Aiswarya. Patel and Shah (1985) observed only three instars for *L. pygmaea* in Gujarat.

Pupal period

The grub pupated on the surface of the leaf as a brown coloured pupa (Fig. 1). The pupal period lasted for 3.2 and 2.9 days in Jyothi and Aiswarya respectively. Patel and Patel (1970) also reported that pupal period of *L. pygmaea* was about 4 days which is in agreement with the present finding. Patel and Shah (1985) observed that the pupal period were 4.14 days (at 25–28 °C) and 3.64 days (at 29–30 °C) indicating that pupal period was more in lower temperature. Dalvi *et al.* (1985) observed that the pupal period lasted for 4–5 days in Maharastra.

Total life cycle

L. pygmaea completed its life cycle within a mean period of 14.8 days in Jyothi while it was 13.8 days in Aiswarya. There was a difference of only one day in the mean duration of total life cycle of *L. pygmaea* on Jyothi and Aiswarya thus indicating the absence of marked difference in the duration of life cycle on short and medium duration rice varieties. In Maharashtra, Dalvi *et al.* (1985) reported that rice blue beetle completed its life cycle in 22–24 days. The shorter duration of life cycle in the present study might be due to the difference in weather conditions in the two regions.

Pre-oviposition period

The mean pre-oviposition period was observed to be 21.0 and 20.3 h on Jyothi and Aiswarya respectively (Table 1). The mean pre-oviposition period in *L. pygmaea* was reported to be 4.9 days in Gujarat (Patel and Shah, 1985) and 2.6 days in Maharastra (Dalvi *et al.*, 1985).

Adult longevity

Longevity is important not only for its influence on demographics but also because it determines how long the pest is active and exerts a negative influence on the crop. The adult beetles are metallic blue coloured and black coloured on the ventral side of the body (Fig. 1). The longevity of adult varied with the sex of rice blue beetle. Male beetles lived longer than females. The male beetle had an average life span of 40.9 and 36.7 days in Jyothi and Aiswarya respectively (Table 1). The mean longevity of female beetle was 24.9 and 24.7 days in Jyothi and Aiswarya. Adult longevity was found to be higher on Jyothi than Aiswarya. This result is contrary to the earlier findings of Patel and Shah (1985) in Gujarat, where there was no marked difference in the longevity of male and female rice blue beetles. They found the adults lived a longer life of 19 days in March/April when maximum temperature fluctuated above 30 °C. During July–September, when maximum temperature was below 30 °C the adult beetles lived for 15–16 days. In Maharashtra, the adult beetles were found to have longevity of 18–35 days during kharif season (Dalvi *et al.*, 1985). The difference in the present results might be due to temperature and other prevailing rearing conditions.

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(Received 28 November 2007; accepted 15 February 2008)

ENTOMON **33(1)**: 41–46 (2008)
Article No. ent.33105

Insecticidal efficacy of *Chromolaena odorata* (compositae) on the coconut beetle, *Oryctes rhinoceros* (Linn.)

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ABSTRACT: Different doses of *Chromolaena odorata* plant powder were mixed with cowdung and fed to late third instar grubs of coconut rhinoceros beetle, *Oryctes rhinoceros* (L.). Mortality rates of larval and pupal stages as well as the emergence of deformed adults were recorded. Concentration of 15 and 20% (w/w) plant powder showed 80 and 90% impact respectively on the development of rhinoceros beetle. Topical supply of juvenile hormone analogue, methoprene @ 20 and 30 μg levels to third instar grubs induced 86 and 92% developmental deformities similar to that observed with the supply of 15 and 20% plant powder. Similarity in the induction of morphological deformities in the emerging adults of *O. rhinoceros* by the two treatments indicated the JH mimicking endocrine influence exerted by this plant. These preliminary observations indicate the potential of this common weed for use against *O. rhinoceros*, by incorporating the plant material on the breeding sites of the pest.

KEYWORDS: *Oryctes rhinoceros*, *Chromolaena odorata*,, methoprene

INTRODUCTION

Coconut rhinoceros beetle, *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae) is a serious and well known pest of coconut palm; the adult beetle bores into the unopened fronds and inflorescence of the palm. Adults breed on cow-dung or decaying organic matter on which the larvae feed. Treatment of breeding sites with insecticides is one of the key components of the IPM package for this pest. Application of insecticidal agent

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at the breeding site, where the insect is relatively stationary, potentially would seem more efficient than other methods of control for the highly mobile adult (Campbell and Wright, 1976). However, this could be harmful to its natural predators and also can cause adverse effects on the environment. The present study was carried out to explore the possibility of eco-friendly management of this pest by incorporating plant product with insect control potential in its natural breeding sites. The plant tested is *Chromolaena odorata* (syn: *Eupatorium odoratum* L). Commonly known as Siam weed, Christmas bush, etc., it is a noxious perennial weed in many parts of the world. It was introduced to India from tropical America during the Second World War and since then it has spread widely and has become a dominant weed of wastelands, roadsides and other exposed areas (Kushwaha *et al.*, 1981). Its medicinal properties are also well known.

Rajamma (1982) showed that the application of *C. odorata* leaves into the soil prior to planting of sweet potato reduces the weevil infestation significantly. The moult inhibiting action and formation of malformed adults as a result of application of *C. odorata* extract on *Dysdercus cingulatus* was reported earlier by Saradamma (1989). Prameela (1997) observed that the application of *C. odorata* extract resulted in the inhibition of normal ovarian development and oocyte maturation in the same insect. During fallows between cultivation, *Chromolaena* adds copious amounts of organic matter to the soil and may reduce the population of nematodes (M'Boob, 1991). It is also an useful mulch for row crops (Swennen and Wilson, 1984). Basin application of *Chromolaena* leaves prior to planting of vegetable seedlings is recommended and followed by vegetable growers of Kerala. In pepper, evaluation of leaf and seed extracts of *Strychnos nuxvomica* and *Chromolaena odorata* were promising indicating their potential for utilizing them in IPM schedules (Devasahayam, 2005).

Keeping the above in view, the present study was undertaken. Studies were also conducted on the effect of synthetic juvenile hormone mimic, methoprene on the development of rhinoceros beetle for comparison of observed symptoms.

MATERIALS AND METHODS

Late third instar *O. rhinoceros* (L.) grubs were used for the experiment. Grubs of different stages of growth were collected from local manure pits, vermi-compost units and felled oil-palm residues and were maintained on cow-dung in the laboratory under controlled conditions. Tender stems and leaves of *C. odorata* were collected from Kariavattom campus and nearby areas, shade-dried and pounded to a coarse powder. This powder @ 5, 10, 15 and 20% (w/w) was thoroughly mixed with sun-dried and powdered cow-dung. Cow-dung without leaf powder served as control. Late third instar grubs with a mean weight of 11.2 g were introduced individually into small plastic containers with 100 g of cow-dung-plant mixture. Water was sprinkled over the feed to provide adequate moisture. The containers were covered with plastic lids with holes. The feed was changed once a week. There were 10 grubs per treatment and the experiment was replicated five times. Observations were made on the development of the larvae and deformities, if any, at three days intervals.

TABLE 1. Effect of *Chromolaena odorata* leaf powder on the development of *Oryctes rhinoceros*

Dosage (%plant powder)	Initial no. of larvae	Larval mortality	Pupal mortality	Total mortality	Deformed adults	Deformity score	Total mortality+ Deformed adults
05	10	1.4	0.4	1.8	1.4	0–1	3.2
10	10	2.6	0.6	3.2	3.2	1–2	6.4
15	10	3.6	1.2	4.8	3.2	2–3	8.0
20	10	6.0	1.2	7.2	1.8	3–4	9.0
Nil (control)	10	0.2	0.0	0.2	0.0	-	0.2

Values represent the mean of 5 replications with 10 larvae each.
General mean: 1.787; S.E: 0.560; CV(%): 21.330
Treatments (T) CD: 0.409; Conditions (C ie., Developmental stages of the insect) CD: 0.317; T X C CD: 0.709.

In another experiment, the effect of juvenile hormone analogue, methoprene on the development of third instar *O. rhinoceros* larva was studied. Methoprene (ZR 515, gift from Dr. Govindan Bhaskaran, A&M University, Texas, USA) was dissolved in acetone so that 1 μl contained 1 μg methoprene and the desired dose (10 μg, 20 μg and 30 μg) was applied to different animal groups of ten each in five replications. The hormone was applied topically on the ventral abdominal segment of third instar larvae. Two sets of control were maintained; one set received only acetone in the same dosages and the other received no treatment at all. All the sets of larvae were maintained on cow-dung as described earlier. The treatments were replicated five times and observations recorded as above.

RESULTS

When third instar *O. rhinoceros* larvae were grown on cow-dung mixed with *C. odorata* leaf powder, the first larval mortality was recorded on the sixth day of treatment. Larval mortality was 60% in 20% leaf powder medium, followed by 36% in 15% leaf powder, 26% in 10% leaf powder and 14% in 5% leaf powder (Table 1). Only 2% larval mortality was observed in untreated cow-dung. In case of pupal mortality, 12% each in 20% and 15% leaf powder was recorded followed by 6% and 4% in 10% and 5% leaf powder, respectively. The percentage of abnormal adults was 32 in 15% and 10% leaf powder, 18 in 20% leaf powder and 14 in 5% leaf powder. Pupal mortality and abnormal adults were not found in control. In 20% leaf powder medium, 90% of the insects were affected either by mortality of larva or pupa or emergence of abnormal adults. The percentage of insects thus affected was 80 in 15% leaf powder, 64 in 10% leaf powder and 32 in 5% leaf powder.

Pupal-adult intermediates were observed in treatments, which were characterized by adult head, pupal wing buds and retension of pupal exuviae. They lived only up to five

TABLE 2. Effect of methoprene on the development of *Oryctes rhinoceros*

Dosage	Initial no. of larvae	Larval mortality	Pupal mortality	Total mortality	Deformed adults	Deformity score	Total mortality+ Deformed adults
10	10	1.2	0.2	1.4	4.8	1–2	6.2
20	10	2.0	0.4	2.4	6.2	3–4	8.6
30	10	3.4	0.8	4.2	5.0	2–3	9.2
Acetone							
30	10	0.0	0.0	0.0	0.0	–	0.0
Nil	10	0.0	0.0	0.0	0.0	–	0.0

Values represent the mean of 5 replications with 10 larvae each.
General mean: 1.573; S.E: 0.510; CV(%): 22.439
Treatments (T) CD: 0.373; Conditions (C) (i.e. Developmental stages of the insect) CD: 0.289; T x C CD: 0.647

days whereas those adults with badly deformed wings survived up to nine days. The emerged adults other than malformed were normal looking but with pale, leathery, unchitinized wings not covering the abdomen fully. Around 80% of them had longevity of 24–30 days. From control larvae, normal adults emerged and lived beyond 95 days. More than 80% of emerged adults were females and abnormal morphological characters were manifested more in females. The pygidium of normal looking and deformed adult females under plant product treatment was not densely packed with reddish-brown sensory hairs whereas it was bushy in control adult females. This may be due to some abnormalities in the reproductive system of treated larvae.

When treated with methoprene, 34% larval mortality was recorded at 30 μg dose, followed by 20% at 20 μg and 12% at 10 μg (Table 2). Pupal mortality was 8%, 4% and 2% respectively at the above doses. Highest abnormal adults (62%) was recorded at 20 μg methoprene followed by 50% at 30 μg and 48% at 10 μg. Treatment with 30 μg methoprene affected 92% of the insects either by mortality of larva or pupa or production of abnormal adults; 20 μg methoprene affected 86% of the insects and 10 μg methoprene affected 62% of the insects. The morphological deformities observed in adults emerged out of this treatment was similar to that produced by exposure to *C. odorata* leaf powder. No larval or pupal mortality or abnormal adults were found in the two controls.

DISCUSSION

From the present results, it is inferred that *Chromolaena odorata* has exerted JH like activity during the metamorphosis of this insect as evidenced through the emergence of adults with varying external deformities, occurrence of pupal-adult intermediates and premature death of adults inside the pupal case. The chemical properties of juvenoids usually allowed them to cross the cuticle and act directly on the insect as a result of contact. Since ingested JH like substances are likely to be digested before absorption,

the effect observed here seems to be due to external skin contact of larvae with the plant material.

Growth regulatory activity including larval and pupal mortality as well as deformation of adults in *Oryctes rhinoceros* was reported with *Clerodendron infortunatum* (Chandrika and Nair, 2000). Further, the results of the present study agree with the findings of Ponnamma (2003) that crushed leaves of *C.odorata*, when mixed with sterilized cow dung and fed to third instar grubs of *O. rhinoceros*, caused abnormalities and prevented proper development of beetles. The insecticidal and insect growth regulatory activity exerted by organic extracts from the leaves of *Vitex mollis* was recently reported by Rodriguez-Lopez *et al.* (2007). Plant kingdom offers an excellent source of secondary metabolites which affect the behaviour, physiology, growth, reproduction and development of insects. Many of them exert repellence effect, feeding deterrence and several other influences. Some affect the hormonal balance of the insects while some others are highly toxic and affect normal physiological processes. Many juvenoids have been isolated from plants and the possibility of using these phytojuvenoids in disrupting the insect developmental processes forms an innovative and effective control strategy for the management of insect pests. The use of these growth regulating compounds would be more appropriate, when the insect is a pest during its adult stage and the larvae develop in a restricted habitat (Elzinga, 2000). The effects produced by *C. odorata* leaf powder and the JHa methoprene on *O. rhinoceros* showed resemblances in their morphological abnormalities indicating the presence of juvenile hormone mimics in the tested plant.

The search and use of safer plant-derived products are increasing now as a viable component of Integrated Pest Management (IPM). Results of the present study suggest the possibility of incorporating *C. odorata*, a common weed plant available in plenty in coconut orchards, in the breeding sites of *O. rhinoceros*, as an ecologically safer, human hazard free, farmer-friendly component among the existing IPM package developed for the management of *O. rhinoceros*.

ACKNOWLEDGEMENTS

The first author thanks the Director, Central Plantation Crops Research Institute, ICAR, Kasaragod for grant of study leave to undertake research work leading to Ph.D degree at Kerala University, and Professor & Head, Department of Zoology, Kerala University, Trivandrum for extending facilities.

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(Received 4 January 2008; accepted 15 February 2008)

ENTOMON 33(1): 47–51 (2008)
Article No. ent.33106

Population dynamics, species composition and feeding site preference of rice black bug (hemiptera: pentatomidae) infesting rice

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ABSTRACT: The incidence of rice black bug in different periods in rice fields was monitored in South Tamil Nadu. Maximum nymphs and adults were recorded during January. This coincided with 97th day after transplanting (DAT) followed by 87 and 45 DAT. Two species of black bug were seen in the population, *Scotinophara coaractata* (Fab.) and *S. lurida* (Burm.), the latter being very scarce (2.5 to 1.0 % of total catch) in all the months. The nymphs and adults preferred the leaf node for feeding.

KEYWORDS: rice black bug, *Scotinophara coaractata*, stink bug

INTRODUCTION

Stink bugs of the genus *Scotinophara* are common pests of rice in several Asian countries (Miyamota *et al.*, 1983). Of the six *Scotinophara* sp. present on rice in the Phillipines, only *S. coaractata* (F.) was reported as a serious pest (Barrion *et al.*, 1982). Earlier reports suggested that it was an introduced pest (Miyamota *et al.*, 1983) but it may be that its pest status has only recently been recognized. Though it is reportedly an introduced pest in many countries its entry into India lacks evidence. In Tamil Nadu introduced pest in many countries its entry into India lacks evidence. In Tamil Nadu sporadic but severe outbreaks of the pest was reported by Uthamasamy and Marriappan (1985) and Subramanian *et al.* (1986). Rice black bug hitherto considered as a minor pest has become a menace during the past five years.

MATERIALS AND METHODS

The present investigation was undertaken to study the population dynamics, species complex and the host preference of black bugs infesting rice at Agricultural College

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and Research Institute, Killikulam, Tamil Nadu. For studying the population dynamics a field experiment was conducted in the central farm of the college in Pishanam season planting ASD-16 variety and following recommended agronomic practices. The population was assessed by counting the number of nymphs and adults visually from 40 hills at random commencing from 12 days after transplanting at monthly intervals. The affected hills were removed, placed in plastic bags and transported to the laboratory and the nymphs and adults were counted and recorded. Each represented a sampling unit. Sampling was carried out over a ten months period.

Population abundance of black bug during one cropping season was also assessed in IR-20 variety in the field. The total population of nymphs and adults were counted in 10 hills at random from 27–97 days after transplanting at 10 day intervals. The identification of species complex was made through light trap collection. The light traps were installed in the field and the trap was fitted with incandescent bulb (100W). Daily catches collected between 7 PM to 6 AM were counted. Adult pentatomid bugs of *Scotinophara* sp. collected from the light traps were separated, sorted out and identified by taxonomic characters (Barrion *et al.*, 1982). Predominant species in every month were recorded.

In a net house study the preferred feeding sites of black bug was observed. Bugs were released on 30–35 days old ADT-36 (a rice variety highly susceptible to black bug) at panicle initiation stage and covered with Mylar cages which enclosed 7 adults/plant with suitable control (plant with no bug). Treatments were replicated thrice. The insect feeding at nodal, stem, leaf and panicle stages were assessed.

RESULTS AND DISCUSSION

Data on the incidence of black bug in different periods in field condition are shown in Table 1. Weekly in situ counts of the nymphs and adults from 40 hills at random revealed maximum population in the month of January (220 numbers) and beyond that the incidence gradually decreased. Population of nymphs and adults showed the same trend. Ferer and Shepard (1987) studied the light trap catches of black bug and recorded the peak activities in mid August and mid April and June. The effect of growth stage of the plants on the population of black bug is presented in Table 2. The population significantly varied among the age of the crop. The mean maximum population was recorded at 97 DAT (162 numbers) followed by 87 DAT (141 numbers) and 47 DAT (113 numbers). This is in agreement with the earlier reports of Abdul Latif *et al.* (1982) and Saroja *et al.* (1993).

Table 3 shows the species of black bug in different periods. The data clearly establish the dominance of *S. coaractata* throughout the cropping season compared to *S. lurida*. Peak population was recorded in March, May, June and September (100%) and smaller peaks were evident in February (94.6%). Saroja (1991) recognized that *S. coaractata* was the predominant species and accounted for 97% incidence in Chengalpattu district of Tamil Nadu. Within the district level survey occurrence of the two species showed variations and *S. coaractata* was the most common species.

TABLE 1. Seasonal incidence of black bug in different periods in field condition

Months	Population No./40 hills		
	Nymph	Adult	Total
Dec	50 (7.07)^{f}	112 (10.58)^{d}	162 (17.65)^{e}
Jan	80 (8.95)^{b}	140 (11.83)^{a}	220 (20.78)^{a}
Feb	67 (8.15)^{d}	126 (11.23)^{b}	193 (19.42)^{d}
Mar	40 (6.33)^{h}	93 (9.64)e	133 (15.97)^{f}
Apr	27 (5.26)^{e}	46 (6.78)^{h}	73 (12.04)^{h}
May	15 (3.87)^{j}	32 (5.66)^{i}	47 (9.53)^{j}
June	47 (6.86)^{g}	22 (4.69)^{j}	69 (11.55)^{i}
July	136 (11.66)^{a}	71(8.43)^{f}	207 (20.09)^{b}
Aug	59 (7.68)^{i}	58 (7.62)^{g}	117 (15.30)^{g}
Sep	78 (8.83)^{c}	123 (11.09)^{c}	201(19.92)^{c}

Values represent the mean of three replications. In a column, means followed by the common letter are not significantly different ($P = 0.05$) by LSD; DAT - Days after transplanting.

TABLE 2. Population of black bug at different periods of crop growth observed in field condition

Days after	Population No./10 hills		
transplanting	Nymph	Adult	Total
27	0.5 (0.71)^{a}	8 (2.83)^{a}	8.5 (3.54)^{a}
37	23 (4.79)^{b}	58 (7.62)^{d}	81 (12.47)^{b}
47	54 (7.35)^{d}	59 (7.68)^{d}	113 (15.03)^{e}
57	52 (7.21)^{c}	43 (6.56)^{c}	95 (13.77)^{d}
67	58 (7.62)^{e}	35 (5.92)^{b}	93 (13.54)^{c}
87	69 (8.31)^{f}	72 (8.49)^{e}	141 (16.80)^{f}
97	52 (7.21)^{c}	110 (10.49)^{f}	162 (17.70)^{g}

Values represent the mean of three replications. In a column, means followed by the common letter are not significantly different ($P = 0.05$) by LSD.

TABLE 3. Species complex of *Scotinophara* in different periods obtained from light trap catch

Months	*S. coaractata*		*S. lurida*	
	No.	Percentage in total catch	No.	Percentage in total catch
Dec	156	97.5	4	2.5
Jan	289	98.0	6	2.0
Feb	35	94.6	6	2.0
Mar	10	100.0	0	–
Apr	192	99.0	2	1.0
May	5	100.0	0	–
June	9	100.0	0	–
July	85	97.7	2	2.3
Aug	39	97.5	1	2.5
Sep	7	100.0	0	–
Mean	82.7	98.4	17	1.57

TABLE 4. Preferred feeding sites of black bug

Plant part fed	Insect feeding in %	
	Nymphs	Adults
Node	73^{a}	88^{a}
Stem	68^{a}	73^{b}
Leaf	43^{b}	8^{d}
Panicle	28^{c}	18^{c}

Values represent the mean of three replications. In a column, means followed by the common letter are not significantly different ($P = 0.05$) by LSD.

The preference of feeding sites of the black bug is shown in Table 4. Among the different plant parts, nodal portion was most preferred by the adults and nymphs (88 and 73%) followed by stem (73 and 68%) and leaf petiole (8 and 43). This is in consonance with the report of Saroja *et al.* (1993).

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(Received 29 June 2007; accepted 15 February 2008)

ENTOMON **33(1):** 53–64 (2008)
Article No. ent.33107

Revival and recharacterization of genus *Thyrgorina* walker (Lepidoptera: Arctiidae: Arctiinae) and taxonomic studies on four Indian species of this genus from Western Ghats of India

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ABSTRACT: Genus *Thyrgorina* Walker has been revived from the synonymy of *Diacrisia* Hübner and recharacterized in detail by including external male and female genitalic structure of its type species. External genitalic structure of Indian species i.e. *Thyrgorina indica* (Guer), *T. angularis* (Strand) and *T. exima* (Swinhoe) have been studied and illustrated for the first time besides reporting of a new species viz. *T. coorgensis* sp.nov. from Western Ghats of India. The description of new species is discussed in detail.

KEYWORDS: Arctiinae, Lepidoptera, *Thyrgorina*, revalidation, new species

INTRODUCTION

Genus *Thyrgorina* was established by Walker in 1864 with *indica* Guer as the type species with range from Himalayas to Nilgiris in India, and Myanmar. Hampson in 1894 described as many as 14 species under genus *Thyrgorina* Walker from different areas of then British India. Hampson (1901) synonymised this genus under *Diacrisia* Hübner and the same nomenclature was followed by Strand in 1922. Koda (1988) while giving the generic classification of Arctiinae of the Palearctic and Oriental regions based on the male and female genitalia shifted some of the species previously placed under genus *Thyrgorina* Walker to *Thanatarctia* Butler suggesting new combinations.

During the present studies, as many as four species i.e., *indica* Guer, *angularis* Strand, *eximia* Swinhoe and *malshejensis* sp. nov. were collected and studied in detail. The critical examination of the type species of genus *Thyrgorina* Walker i.e., *indica* Guer reveals that it is generically distinct from type species of genus *Diacrisia* Hübner. The male and female genitalic structures of remaining three species have also been studied in detail and these are completely congeneric with the type species *indica* Guer. In this light, genus *Thyrgorina* Walker has been removed from the synonymy

of genus *Diacrisia* Hübner and is being revived and recharacterized by incorporating male and female genitalic characters in its diagnosis. A key to the four studied species is given below. One of the species could not be identified form the relevant literature or by comparison from different national museums and Natural History Museum, London. Therefore, it is being proposed as new species, *malshejensis* sp. nov. here.

MATERIALS AND METHODS

The material for the present studies i.e. the adult moths of sub-family Arctiinae were collected at night using fluorescent light from different localities of Western Ghats of India. The moths thus collected were killed with ethyl acetate in the killing bottle. The freshly killed specimens were pinned and stretched on adjustable wooden stretching box. The pinned specimens were dried for 2–3 days in the improvised drying chambers fitted with electric bulb. The properly dried specimens were then preserved in air tight wooden boxes, containing naphthalene balls as fumigant. The method proposed by Common (1970) and advocated by Zimmerman (1978) has been followed for the preparation of permanent slides of fore and hindwings. For the study of external male genitalia, the entire abdomen of preserved moths was removed, as cutting the last few segments often damages the constituent parts of male and female genitalia (Robinson, 1976). The detached abdomen was put in 10% KOH for 12–14 h to soften the chitin and to dissolve away the muscles and other soft parts. The KOH treated material was washed in distilled water and residual traces of KOH were later removed using 1% glacial acetic acid. The abdomen was dissected in 50% alcohol for taking out the genitalia and the adhering unwanted material was cleared off in the subsequent grades. After proper dehydration, the material was cleared in clove and preserved in alcohol-glycerol. The diagrams were drawn with the help of graph eye piece fitted in the zoom binocular.

RESULTS AND DISCUSSION

Genus Thyrgorina Walker gen. rev.

Walker, 1964, *List. Spec. Lepid. Ins. Coll. Br. Mus.*, **31**: 37.

Type species *Arctia indica* Guer.

Distribution India: Himalayas, Mumbai, Nilgiri Hills (Tamil Nadu); Myanmar.

Diagnosis:

Labial palpi porrectly downward. Antennae bipectinate in males, serrate in females. Forewing with vein R_2, R_3, R_4 and R_5 stalked; M_1 from upper angle of cell; M_2 and M_3 from lower angle of cell. Hindwing with vein $Sc + R_1$ originating towards base of cell; M_2 and M_3 from or near lower angle of cell. Hind tibia with two pair of spurs. Male genitalia with uncus long, broad at base and narrowing towards tip; acrotergite weakly developed; fenestrula triangular; valvae simple with costa narrow and sacculus

well differentiated, ampula not distinct; aedeagus long; vesica membranous with well formed patch of sclerotized spines; ductus ejaculatorius entering subapically. Female genitalia with corpus bursae membranous, signum absent.

***Thyrgorina indica* (Guer) comb. rev. (Fig. 1)**

Arctia indica Guer, 1843, *Deless, Souv. Inde.*, **2**: 9.3
Thyrgorina spilosomata (Walker, 1864), *Cat. Lep. Het.*, **31**: 318.
Thyrgorina indica (Guer, 1843) Hampson, 1894, *Fauna Br. Ind. Moths*, **2**: 12
Diacrisia indica (Guer, 1843) Hampson, 1901, *Cat. Lep. Het.*, **3**: 265

Male genitalia

Uncus strongly built, beak-like, well sclerotized, setosed with small seate, broad at base, tip pointed; acrotergite weakly developed; fenestrula triangular; tegumen as long as uncus, u-shaped; vinculum slightly shorter than tegumen, weakly sclerotized, v-shaped; saccus present. Valvae with costa and sacculus differentiated; harpe + ampula simple; cucullus produced to a snout, tip blunt; valvula a small outgrowth on lateral side. Juxta oval with a protrusion at distal end; aedeagus long and narrow; vesica membranous with series of sclerotized spines; ductus ejaculatorius entering subapically.

Female genitalia

Corpus bursae funnel shaped, broad at posterior region and cylindrical towards anterior region, membranous, signum absent; ductus bursae moderately long, broad at both ends and narrowing towards central region, weakly sclerotized; ductus seminalis entering at junction of corpus bursae and ductus bursae; anterior apophyses shorter than posterior apophyses; papilla analis fringed with short setae.

Wing span Male 32–34 mm; female 40–44 mm.

Material examined

Gujarat:	Saputara (970 m), 29. ix.05 – 2♂♂
Maharashtra:	Matheran (690 m), 5.x0.5 - 9♂♂ 1♀; Mahabaleshwar (1320 m), 8.x.05 – 1♂; Malshej Ghat (690 m), 1.x.05 1♂.
Tamil Nadu:	Coonoor (1880 m), 2.x.03 - 1♂
Kerala:	Devikulum (1620 m), 13.ix.04 – 1♂, 14.ix.04 - 4♂♂; Vallakadav (780 m), 11.ix.04 –3♂♂ 1♀.

Old distribution India: Mumbai and Nilgiri Hills (Tamil Nadu)

Remarks

As mentioned under the remarks of genus, the original status of genus *Thyrgorina* Walker has been restored in the present study and the external male and female genitalia of its type species i.e. *indica* Guer are discussed and illustrated here in detail.

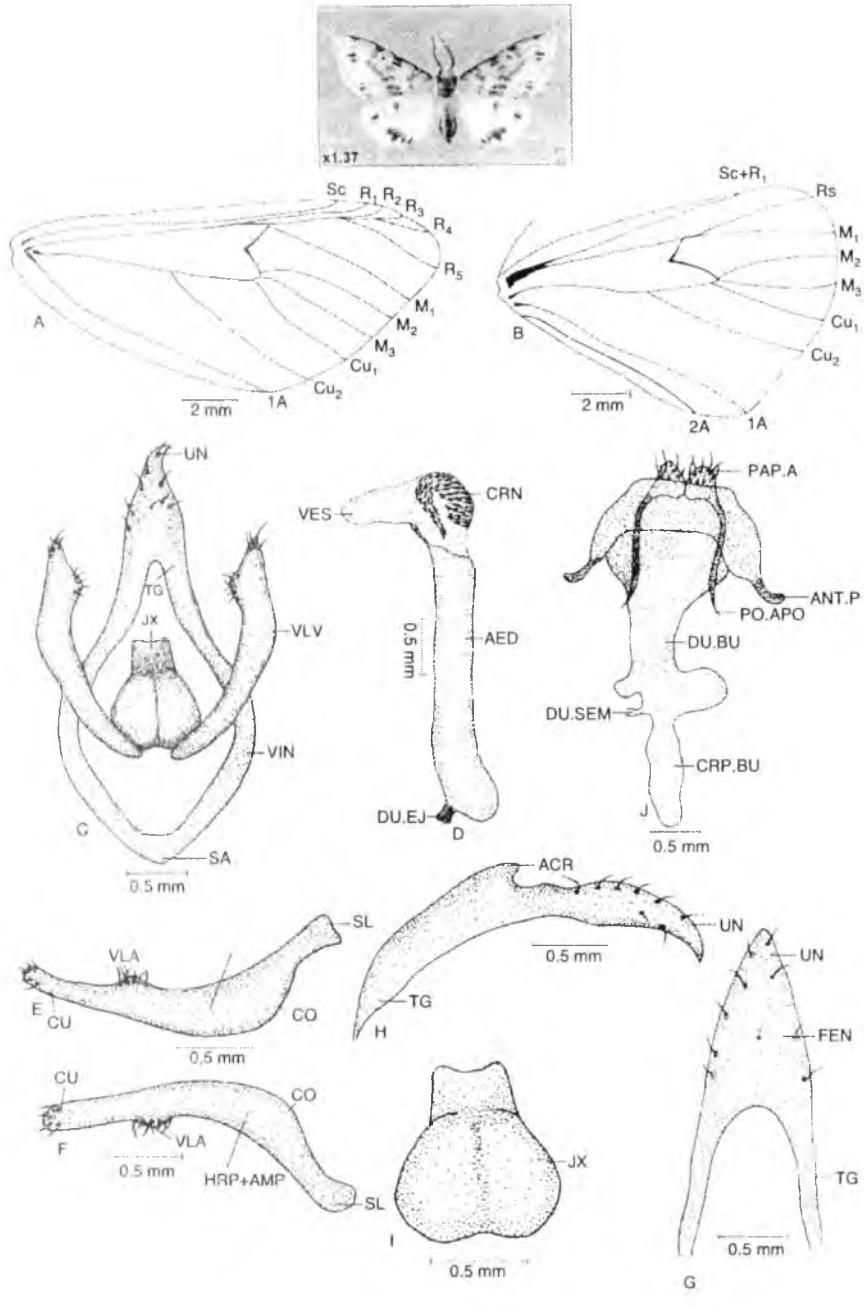

FIGURE 1. *Thyrgorina indica* (Guer) comb. rev. (A) Forewing; (B) Hindwing; (C) Male genitalia; (D) Aedeagus; (E) Valva (right); (F) Valva (left); (G) Uncus with Tegumen (dorsal view); (H) Uncus with Tegumen (lateral view); (I) Juxta (enlarged); (J) Female genitalia.

***Thyrgorina angularis* (Strand) stat. nov. (Fig. 2)**

Diacrisia indica Guer ab. angularis Strand; Strand 1919, Arctidae: Arctiinae. Lep. Cat. **22**: 182.

Head Frons and vertex white. Antennae bipectinate in males, serrate in females; scape and pedicel covered with white scales; shaft and branches brown with slight suffusion of white scales. Eyes fuscus grey, densely spotted with black. Labial palpi porrectly downward; underside covered with ochreous scales; lateral side black; third segment black and bent downward.

Thorax White; tegula furnished with white hair like scales; collar white having suffusion of yellow scales.

Forewing Ground colour white; base of the costa black brown; a spot at end of cell; veins paler; underside same with postmedial series of three spots; fringe white; vein R_1 originating from cell; R_2, R_3, R_4 and R_5 stalked; M_1 from upper angle of cell; M_2 and M_3 from lower angle; Cu_1 near lower angle; Cu_2 from middle of cell.

Hindwing Ground colour white; a black spot at end of cell; submarginal black spots under vein Cu_2; a black spot at vein M_2; underside same; fringe white; vein $Sc + R_1$ originating near base of cell; Rs and M_1 from upper angle of cell; M_2 and M_3 from lower angle; Cu_1 very near to lower angle; Cu_2 from middle of cell. Legs covered with white scales; outer surface of tibia and tarsus black brown; hind tibia with two pair of spurs.

Abdomen Yellow with first segment white; dorsal, lateral and sublateral series of black spots; underside and tuft white.

Male genitalia

Uncus broad at base and narrowing towards tip, setosed with small setae, well sclerotized, tip pointed and curved; acrotergite poorly developed; fenestrula triangular; tegumen longer than uncus, u-shaped; vinculum shorter than tegumen, sclerotized, u-shaped, saccus developed. Valvae simple with costa weakly sclerotized; sacculus well sclerotized, produced to an outgrowth towards distal end; harpe+ampulla simple; cucullus simple; valvula with a small outgrowth. Transtilla weakly sclerotized; juxta almost rectangular with a protrusion towards distal end and a notch at proximal end; aedeagus moderately long and broad; vesica membranous with a patch of small sclerotized spines; ductus ejaculatorius entering subapically.

Female genitalia

Corpus bursae oval, membranous, signum absent; ductus bursae moderately long and broad, well sclerotized; ductus seminalis entering at junction of ductus bursae and corpus bursae; anterior apophyses shorter than posterior apophyses; papilla analis setosed with long setae.

Wing span Male 32 mm; female 40–42 mm.

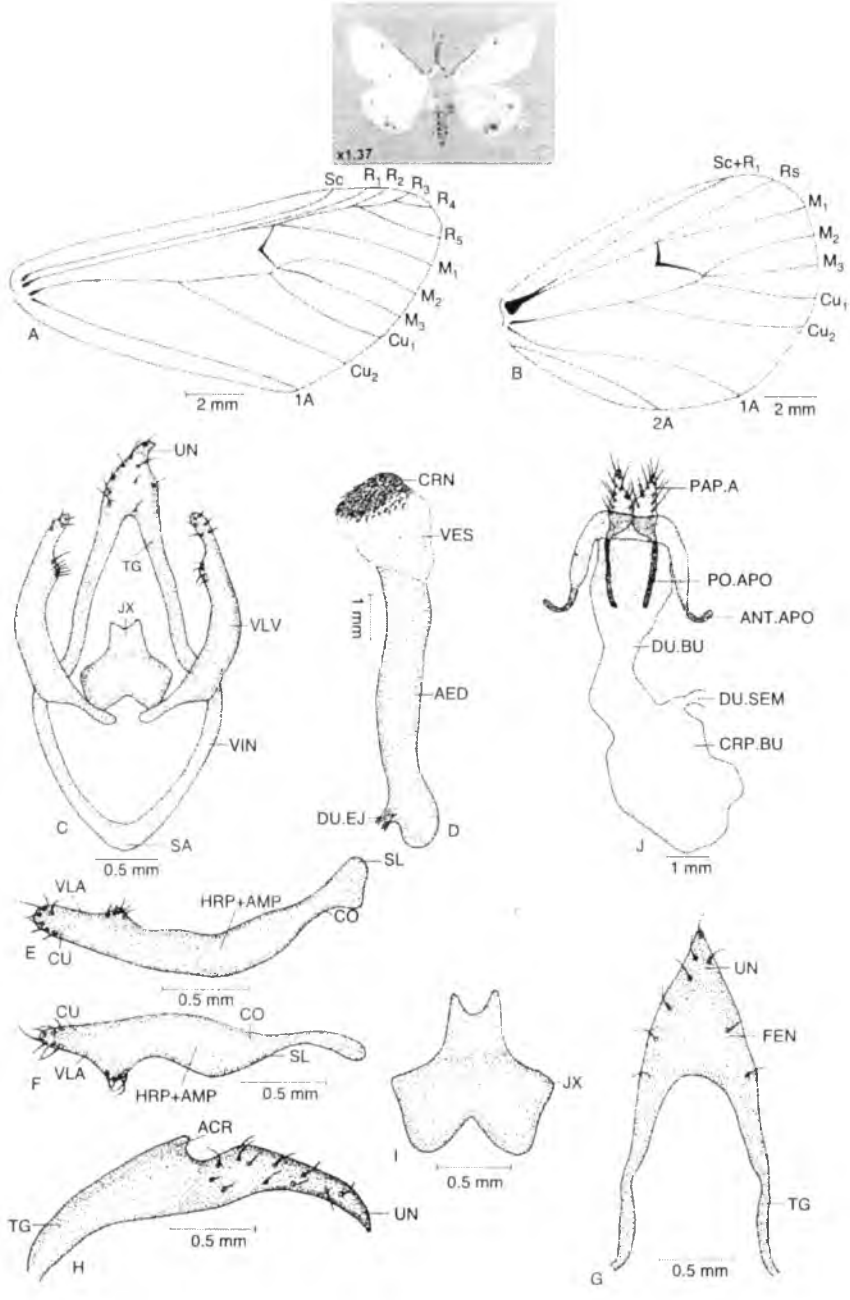

FIGURE 2. *Thyrgorina angularis* (Strand) stat. nov. (A) Forewing; (B) Hindwing; (C) Male genitalia; (D) Aedeagus; (E) Valva (right); (F) Valva (left); (G) Uncus with Tegumen (dorsal view); (H) Uncus with Tegumen (lateral view); (I) Juxta (enlarged); (J) Female genitalia.

Material examined

Gujarat:	Ahwa (520 m), 28.ix.05 – 1♂; Saputara (970 m), 29.ix.05- 2♂♂; 3♀♀.
Maharashtra:	Mahabalehwar (1320 m), 8.x.05 –1♂, 9.x.05 – 1♂, Malshej Ghat (690 m), 1.x.05 – 1♂.
Kerala:	Devikulam (1620 m), 13.ix.04 – 1♀, 14.ix.04 – 1♂.

Old distribution India: Mumbai, Nilgiri Hills (Tamil Nadu) and Coimbatore.

Remarks

While describing species *indica* Guer, Hampson (1901) discussed its representatives with spots of forewing reduced to one at upper angle of cell as a distinct 'form' under *Diacrisia indica* Guer. Strand (1919) named this 'form' as *angularis* Strand. The detailed study of the species under reference reveals that, basides external morphological characters it can be separated from *indica* Guer on the basis of external genitalic structures like shape of juxta, arrangement of spines in vesica of male genitalia and distinct shape of corpus bursae of female genitalia. Therefore, the 'form'; described by Hampson and Strand i.e. *angularis* Strand has been upgraded here by giving it its specific status.

THYRGORINA MALSHEJENSIS SP. NOV. (FIG. 3)

Head

Frons and vertex ochreous. Antennae bipectinate in males, serrate in females; scape, pedical and shaft covered with buff scales; branches brown. Eyes yellowish green, densely spotted with black. Labial palpi porrectly downward; laiden with ochreous scales; tip of third segment black.

Thorax Ochreous, collar and tegula covered with ochreous bordered fuscus, spots; pectus ochreous.

Forewing

Ground colour ochreous; a basal brown patch; diffused subbasal, antemedial, medial and postmedial brown bands; underside same; fringe ochreous; vein R_1 from cell; R_2, R_3, R_4 and R_5 from a common stalk, M_1 near upper angle of cell; $M_2$and M_3 from lower angle of cell; Cu_1 near lower angle; Cu_2 from middle of cell.

Hindwing

Ground colour ochreous; discal cell, vein IA and median nervure suffused with brown scales; more or less complete post medial brown bands; underside same; fringe ochreous; vein $Sc+R_1$ originating before middle of cell, Rs and M_1 on a short stalk; M_2 and M_3 from lower angle; Cu_1 near angle of cell; Cu_2 from middle of cell. Legs ochreous with slight suffusion of fuscus scales; hind tibia with two pairs of spurs.

Abdomen Orange yellow; dorsal and lateral series of black spots; underside covered with buff scales.

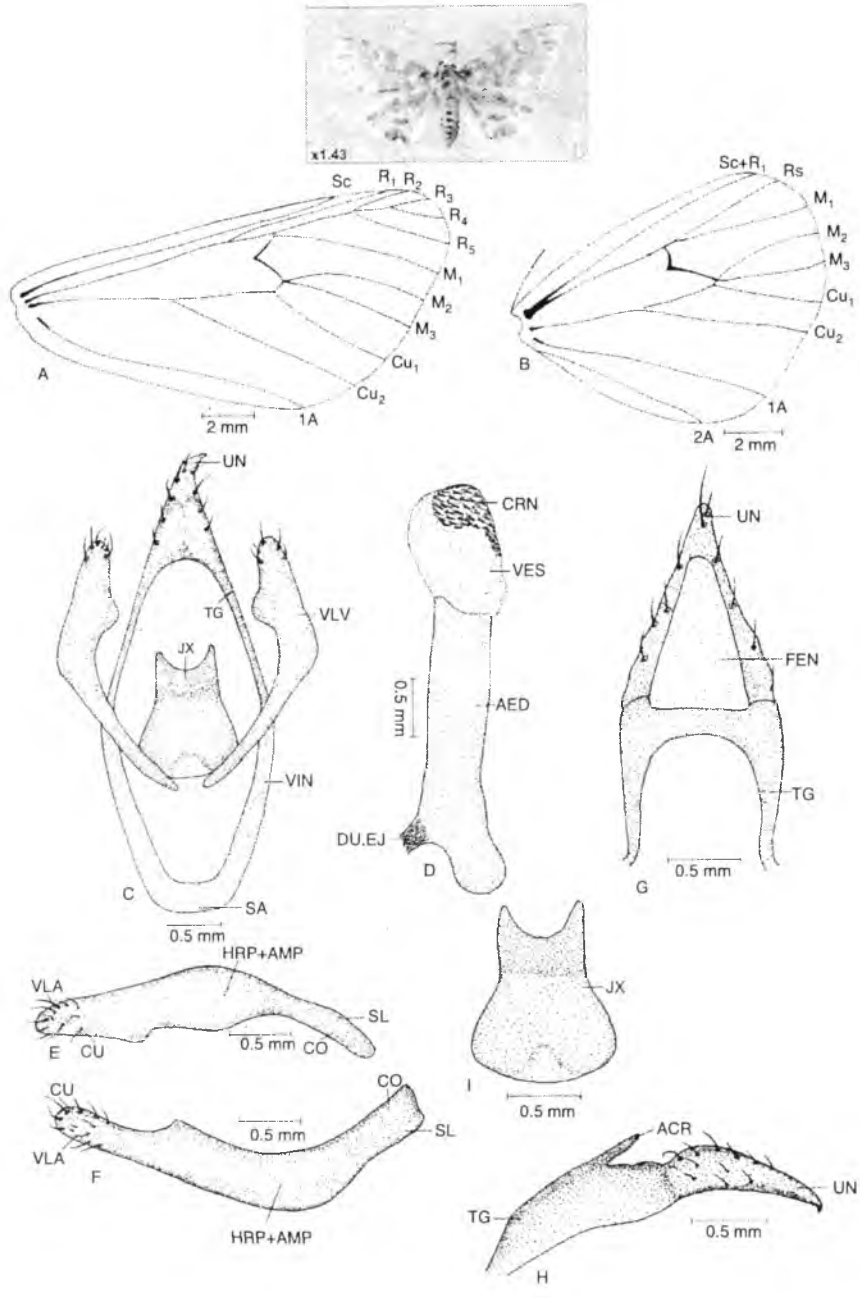

FIGURE 3. *Thyrgorina malshejensis* sp. nov. (A) Forewing; (B) Hindwing; (C) Male genitalia; (D) Aedeagus; (E) Valva (right); (F) Valva (left); (G) Uncus with Tegumen (dorsal view); (H) Uncus with Tegumen (lateral view); (I) Juxta (enlarged).

Male genitalia

Uncus long, broad at base and gradually narrowing towards tip, slightly wavy at ventroproximal region, setosed with small setae, tip minutely blunt; acrotergite present; fenestrula triangular; tegumen longer than uncus, u-shaped; vinculum shorter than tegument, well sclerotized, deep u-shaped, saccus weakly developed. Valvae with costa narrow and linear, weakly sclerotized; sacculus well differentiated, folded, produced to an outgrowth towards proximal end; harpe + ampulla simple plate like; cucullus with a small outgrowth, produced to narrow snout, tip rounded; valvula with small setae, well sclerotized. Transtilla sclerotized; juxta pot shaped; aedeagus long and broad, almost straight; vesica membranous with a single patch of well formed large sclerotized spines; ductus ejaculatorius entering laterally.

Wing span Male 32 mm.

Material examined

Holotype: Maharashtra: Malshej Ghat (690 m), 2.x.05 -1♂
Paratype: Maharashtra: Malshej Ghat (690 m), 2.x.05 -1♂

Remarks

The species under reference is closely allied to *Thyrgorina flavens* Moore as far as the ground colour and some markings of forewing and abdominal markings are concerned. But it differs from *flavens* Moore with respect to merged medial and postmedial bands which give almost uniform appearance and hindwing with irregular markings. As discussed under the remarks of genus the present species could not be identified from the relevant literature and by comparison with the identified collections of Natural History Museum, London. The species is unique and does not conform to the characterization of other species of genus *Thyrgorina* Walker. Hence, the species has been proposed as new to science.

Etymology

The species is named after its type locality i.e. Malshej Ghat in the state of Maharashtra.

THYROGORINA EXIMIA (SWINHOE) COMB. REV. (FIG. 4)

Alpenus eximia Swinhoe, 1891, *Trans. Ent.Soc.*, **1891**: 137.

Thyrgorina eximia (Swinhoe, 1891) (Hampson, 1894), *Fauna Br. Ind. Moths*, **2**: 14.

Diacrisia eximia (Swinhoe, 1891) (Hampson, 1901), *Cat. Lep. Phal.*, **3**: 301.

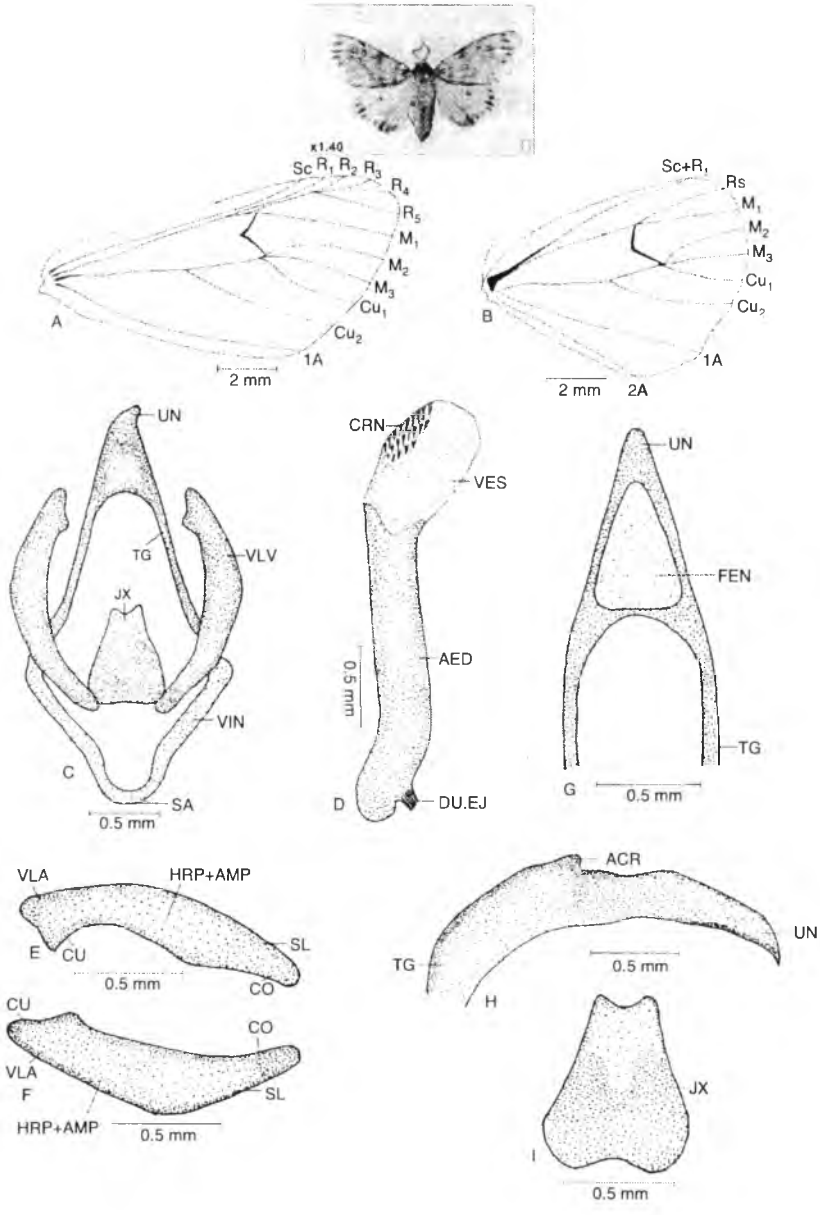

FIGURE 4. *Thyrgorina eximia* (Swinhoe) comb. rev. (A) Forewing; (B) Hindwing; (C) Male genitalia; (D) Aedeagus; (E) Valva (right); (F) Valva (left); (G) Uncus with Tegumen (dorsal view); (H) Uncus with Tegumen (lateral view); (I) Juxta (enlarged).

Male genitalia

Uncus long and narrow, slightly curved at tip, well sclerotized, setae absent; acrotergite weakly developed; fenestrula triangular; tegumen as long as uncus, u-shaped; vinculum shorter than tegumen, well sclerotized, u-shaped; saccus developed. Valvae simple, with inner walls unequally sclerotized; cucullus produced laterally to form a spine like structure. Transtilla sclerotized bar like; juxta pear shaped; aedeagus moderately narrow and long; vesica membranous, cornuti in the form of group of spines; ductus ejaculatorius entering subapically.

Wing span Male 30–32 mm.

Material examined

Karnataka: Ganeshgudi (480 m), 15.xi.03 – 1♂, 21.vii.07 – 1♂; Jogfalls (480 m), 22.vii.04 – 7♂♂.

Old distribution India: Uttar Kannada.

Remarks

The male and female genitalic structures of the species under reference have been studied and illustrated in considerable details for the first time. These structures completely conform to the characterization of genus *Thyrgorina* Walker; therefore, the old stable combination of this species has been revived in the present studies.

Taxonomic segregation of studied taxa

For the easy segregation of species studied here, the following key has been devised.

KEY FOR SEPARATION OF SPECIES STUDIED

1. Fore and hindwing with ground colour white or creamy white; abdomen with dorsal, lateral and sublateral series of black spots **2**
– Fore and hindwing with ground colour except than white; abdomen without sublateral series of black spots **3**
2. Head with frons black; vertex yellow; male genitalia with juxta oval with a protrusion at distal end; female genitalia with corpus bursae funnel like .. ***indica* (Guer) comb. rev.**
– Head with frons and vertex white; male genitalia with juxta almost rectangular with a protrusion towards distal end and a notch at proximal end; female genitalia with corpus bursae oval ..... ***angularis* (Strand) stat. nov.**
3. Head, thorax, forewing and hindwing with ground colour ochreous; abdomen orange yellow; male genitalia with uncus broad at base, slightly wavy at ventroproximal region, setosed with small setae ..... ***malshejensis* sp. nov.**
– Head, thorax, forewing and hindwing with ground colour orange red; abdomen crimson; male genitalia with uncus comparatively narrow at base, setae absent ***eximia* (Swinhoe) comb. rev.**

ABBREVIATIONS

IA: First anal vein; 2A: Second anal vein; AED: Aedeagus; AMP+HRP: Ampulla & Harpe (fused); ANT.APO: Anterior apophyses; CO: Costa; CRN: Cornuti; CRP.BU: Corpus Bursae; CU: Cucullus; CU_1: First cubital vein; CU_2: Second cubital vein; DU.BU: Ductus Bursae; Du.EJ: Ductus Ejaculatorius, FEN: Fenestrula; Jx: Juxta; M_1: First median vein; M_2: Second median vein; M_3: Third median vein; PAP.A: Papilla Analis; PO.APO: Posterior apophyses; R_1: First radial vein; R_2: Second radial vein; R_3: Third radial vein R_4: Fourth vein; R_5: Fifth radial vein; RS: Radial Sector; SA: Saccus; SC: Subcosta; SC+R_1: Stalk of SC + R_1; SIG: Signum; SL: Sacculus; TG: Tegumen; UN: Uncus; VES: Vesica; VIN: Vinculum; VLA: Valvula; VLV: Valva.

ACKNOWLEDGEMENTS

We are very grateful to Dr. Martin Honey, Natural History Museum, London, who rendered help for the comparison of arctiid collections with the holotypes lying there. Thanks are due to Dr. V.V. Ramamurthy, Head, Division of Entomology, Indian Agricultural Research Institute for allowing the comparison with arctiid collections. The financial help given by Department of Science & Technology, New Delhi under a project entitled 'Taxonomic revision of Indian Arctiidae (Lepidoptera)' is also duly acknowledged.

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(Received 6 December 2007; accepted 15 February 2008)

ENTOMON **33(1):** 65–69 (2008)
Short Communication No. ent.33108

Evaluation of *Bacillus thuringiensis* Berliner subsp. *kurstaki* for management of lepidopteran pests of lac insect

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ABSTRACT: Field trials were conducted to evaluate the commercial formulation of *Bacillus thuringiensis* Berliner subsp. *kurstaki* against two key lepidopteran predators viz., *Eublemma amabilis* Moore and *Pseudohypatopa pulverea* Meyr of lac insect on rainy season crop of *rangeeni* lac insect culture reared on the trees of *Butea monosperma (palas)*. *Bt* formulations with all the concentrations tried (0.008, 0.017, 0.034, 0.05, 0.07, 0.085 per cent) significantly reduced the incidence of predators and increased the yield of broodlac over control. Two sprays of *Bt* formulation (0.05%) at an interval of one month (30 and 60 days of inoculation) significantly reduce the incidence of both the lepidopteran predators and increased the yield of broodlac significantly. However, single spray of *Bt* formulation at a concentration of 0.07% will also reduce the incidence of lepidopteran predators and increase the broodlac yield significantly. In order to get the desired efficacy of biopesticide as with chemical pesticides in suppressing the predators population, the application of *Bt* formulation at a concentration of 0.07% was found to be effective. The increase in broodlac yield amongst various treatments of biopesticide varied to the tune of 4.2–10.2 fold with single spray and 3.2–11.8 fold with double spray of *Bt* formulation.

KEYWORDS: *Eublemma amabilis*, *Pseudohypatopa pulverea, Bacillus thuringiensis kurstaki, Butea monosperma, Kerria lacca*, lac crop

The cultivation of lac crop is an additional source of income for many poor and economically backward families in the rural areas. Like other agricultural crops, the lac crop is also susceptible to pest attack. The lac crop is attacked by a number of predators and parasitoids but the lepidopteran predators mainly *Eublemma amabilis* Moore (Noctuidae) and *Pseudohypatopa pulverea* Meyr (Blastobasidae) are intimately associated with lac culture causing around 40% damage to lack crop (Glover, 1937; Malhotra and Katiyar, 1979). Besides several cultural practices, chemical control measures for managing these lepidopteran pests have also been evolved. Endosulfan

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(Malhotra and Katiyar, 1975, 1979), ethofenprox (Jaiswal *et al.*, 2004), dichlorvos (Mishra *et al.*, 1995, 1996) and diflubenzuron (Bhattacharya *et al.*, 1997) are some recommended insecticides which are safe to lac insect and are effective in management of the lepidopteran pests, if applied at proper time and concentration. Though the quick knock down effect have advantages over the other methods in terms of quality and quantity output specially when there is fear of rain these pesticides may pose environmental hazards in long term use. Microbial control of insect pest is one of the eco-friendly approaches without much harm to environment and *Bacillus thuringiensis* sub sp. *kurstaki* is the most popular microbial agent especially for lepidopteran pests. In order to minimize the use of chemical pesticides, *B. thuringiensis* formulation (Delfin) was evaluated on lac culture against both major lepidopteran predators.

The rainy season crop of *rangeeni* lac (June/July–Oct/Nov) was raised on trees of *Butea monosperma (palas)* in the month of July by inoculating broodlac. The lac insect settled on the shoots of the tree within 15 days and the used up broodlac was removed from the trees within 21 days. There were ten treatments including untreated control, each replicated thrice. Six concentrations of *B. thuringiensis* Berliner subsp. *kurstaki* (0.008, 0.017, 0.034, 0.05, 0.07 and 0.085 per cent) along with recommended concentrations of chemical pesticides viz. endosulfan 0.05%, dichlorvos 0.03% and ethofenprox 0.02% were applied. Water was sprayed in untreated control. The formulation was applied on lac culture growing on shoot of host tree with the help of a rocking sprayer. Two treatments with each concentration viz. single spray at 30 days and two sprays at 30 and 60 days of inoculation was applied. In case of dichlorvos, first spray was applied at 0.02% and second at 0.03% concentration. The randomly selected lac culture samples measuring one meter consisted of lac encrusted sticks from each tree collected at the time of crop maturity in the month of October. They were caged in 60 mesh nylon nets for quantification of incidence of insect predators. The observations on number of *E. amabilis* and *P. pulverea* emerging from caged lac samples were recorded after 45 days of caging.

The data (Table 1) revealed that the *Bt* formulation at a concentration of 0.017 to 0.085 per cent significantly reduced the incidence of *E. amabilis* as compared to control, similar to that found with endosulfan, ethofenprox and dichlorvos. There was no significant difference between control and lowest concentration of *B. thuringiensis* (0.008 per cent). No significant difference in the reduction of predator incidence was observed with single and two sprays indicating that one spray is sufficient to minimise the incidence of *E. amabilis*. Similar results were observed with all the three insecticides. This may be due to fact that the rainy season crop is a short duration crop (110–115 days) and the mating period may be over before second spraying and the development of lac insect reaches a very advanced stage. The larvae of *E. amabilis* concealed within the lac encrustations for feeding the living lac insect and the effect of treatment is not manifested.

The incidence of *P. pulverea* was also significantly lower than the control with all concentrations of *Bt* formulations tried as with three recommended insecticides indicating that *P. pulverea* is more susceptible to *Bt* than *E. amabilis*. However, in

TABLE 1. Effect of *Bacillus thuringiensis vis-á-vis* other recommended pesticides on lepidopteran predators of lac insect

Insecticide	Conc. (%)	Average no. of *Eublemma amabilis* per meter of lac encrustation[1]		Average no. of *Pseudohypatopa pulverea* per meter of lac encrustation[1]		Yield of brood lac (Output to input ratio)[2]	
		Single spray	Two sprays	Single spray	Two sprays	Single spray	Two sprays
Bacillus thuringiensis	0.008	7.90 (20)	7.55 (24)	4.17 (48)	5.97 (23)	1.63 (4.62)	1.50 (4.17)
	0.017	4.44 (55)	3.56 (56)	4.01 (50)	5.92 (26)	1.51 (4.21)	2.29 (6.90)
	0.034	3.83 (61)	3.48 (57)	4.00 (50)	5.33 (73)	1.64 (4.66)	2.04 (6.03)
	0.05	3.01 (70)	2.92 (64)	4.35 (46)	0	2.60 (7.97)	3.70 (11.76)
	0.07	1.85 (81)	1.00 (88)	1.62 (80)	0	2.27 (6.83)	2.75 (8.48)
	0.085	1.93 (81)	0.52 (94)	1.83 (77)	0	3.24 (10.17)	4.12 (3.21)
Edosulfan	0.05	1.90 (81)	0.51 (94)	3.54 (56)	0	4.00 (12.79)	2.87 (8.90)
Ethofenprox	0.02	2.32 (77)	1.33 (84)	1.54 (81)	0	1.54 (4.31)	2.10 (6.24)
Dichlorvos	0.02 & 0.03	4.33 (56)	4.21 (47)	2.40 (70)	1.33 (83)	2.68 (8.24)	2.24 (6.72)
Control		9.89	9.89	8.0	8.0	0.29	0.29
SEm ±		0.73	0.73	0.67	0.67	0.46	0.46
CD (5%)		2.07	2.07	1.90	1.90	1.31	1.31

[1]Figures in parentheses are % reduction over control

[2]Fold increase in yield over control.

respect of one and two sprays, there was no significant difference in the incidence of *P. pulverea* with lower concentrations of *Bt* (=> 0.03%) but with higher concentration, the incidence differ significantly. There was no incidence of *P. pulverea* in lac culture with two sprays of *Bt* (=< 0.05%) and with endosulfan and ethofenprox. The higher sensitivity of *P. pulverea* in comparison to *E. amabilis* may be due to the fact that the larvae of *P. pulverea* may be better exposed to insecticides and biopesticides and also feed on dead lac insect as well as lac encrustation, thereby ingesting more spores of *Bt*. The lowest concentration which effectively reduced the incidence of *P. pulverea* with two applications was found to be 0.05 per cent *Bt* and it is equally effective as recommended concentration of chemical pesticides namely endosulfan and ethofenprox.

The increase in broodlac yield amongst different treatments varied from 4.2–12.8 fold with single spray and 3.2–11.8 fold with double sprays in comparison to control. The yield ratio (input to output) was significantly higher than control with 0.034% and higher concentrations of *B. thuringiensis* but there was no difference between single and two sprays. There was no significant difference in yield between 0.05% endosulfan and 0.085% *Bt* treated lac crop. But yield with lower concentration of *Bt* (< 0.085%) was significantly less than with endosulfan. Hence in order to get the same result in respect to lac yield as with endosulfan, a 0.085% concentration of *Bt* have to be applied. There was no significant difference in yield between 0.02% ethofenprox, dichlorvos and 0.07% or less concentration of *Bt*. Hence it is inferred that *Bt* at a concentration of 0.07% and less gave same results as ethofenprox and dichlorvos. It may be concluded that in order to have better quality of broodlac (less infested with lepidopteran predators) *Bt* at a concentration of 0.05% will be suitable for double spray and 0.07% for single spray.

ACKNOWLEDGEMENTS

We are indebted to Department of Biotechnology, Government of India for funding the project. Encouragement by the Director, Indian Institute of Natural Resins and Gums is also acknowledged with gratitude. Thanks are also due to Shri P. Patamajhi for assistance in field and laboratory work.

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(Received 20 November 2007; accepted 15 February 2008)

ENTOMON 33(1): 71–74 (2008)
Short Communication No. ent.33109

Effect of some selected biopesticides on growth and development of *Spodoptera Litura* fab. (Lepidoptera: Noctuidae) larvae

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ABSTRACT:
Third instar larvae of *Spodoptera litura*, Fab. were fed on sunflower leaves treated with biopesticides *viz.*, *Bacillus thuringiensis* subsp. *kurstaki* Berliner (Btk), nucleopolyhedrovirus of *S. litura* (SlNPV) and azadirachtin. Food consumed was the lowest in Btk treatment. Extended feeding periods were noticed in SlNPV and azadirachtin treatments. The adverse effects of biopesticides on the growth and development of *S. litura* revealed their suitability at appropriate stage in sustainable management of this pest.

KEYWORDS: *Spodoptera litura*, biopesticides, food consumption, sunflower

In recent years, sunflower, *Helianthus annuus* L. is widely grown as an oilseed crop in irrigated and rainfed conditions (DES, 2004). The tobacco caterpillar, *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) as a defoliator assumes the major pest status on sunflower and results in yield reduction. Management of this insect is envisaged with conventional chemical insecticides. However, use of chemical insecticides disturbs the natural balance of crop ecosystem greatly by posing problems to natural enemies and nontarget organisms. An alternative pest management technique is the use of ecofriendly biological insecticides. Larvicidal activity, antifeedant and IGR properties of microbials and botanicals are extensively proved against this pest. However, delayed mortality of the pests caused by most of the biopesticides results in continued feeding and consequent damage to crops. The present study was undertaken to find out the efficacy of selected biopesticides *viz.*, *Bacillus thuringiensis* subsp. *kurstaki* Berliner (Btk), nucleopolyhedrovirus of *S. litura* (SlNPV) and azadirachtin. Their effect on the feeding period, food consumption and utilization by the larvae were examined with a view to assess their importance in a sustainable pest management programme.

Disease free, healthy, freshly moulted third instar larvae of *S. litura* weighing 20–30 mg individually reared on semisynthetic diet (Shorey and Hale, 1965; Subrama-

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nian, 2003) were taken from the culture maintained in the Biocontrol laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore. The larvae were released in polypots containing fresh sunflower leaves obtained from pot culture plants of known weight that were pretreated with different biopesticides *viz.*, *Bacillus thuringiensis* subsp. *kurstaki* Berliner (Btk) (Delfin® 25 WG, Margo Biocontrols Pvt. Ltd., Bangalore), nucleopolyhedrovirus of *S. litura* (SlNPV-CBE strain1) and azadirachtin (Econeem plus®, Margo Biocontrols Pvt. Ltd., Bangalore) using an atomizer and shade dried for ten minutes. Four replications were maintained per treatment with ten larvae per replication. This experiment was performed at room temperature (27 ± 1°C) and relative humidity (70–75 %) in 12 h light, 12 h dark. Initial fresh weights of individual larva were recorded. The weight of larvae, fresh uneaten leaves and faecal matter were recorded at every 24 h interval from the first day of experiment till death/pupation of the test larvae. The weight gain or loss by the individual larva was computed at the end of the experiment. Food ingested was determined by subtracting the weight of uneaten food from weight of food provided. Collective faecal weight was also assessed. Growth indices were worked out as proposed by Waldbauer (1968).

The food consumption levels varied in the different treatments (Table 1). The consumption rate was the highest in untreated check followed by the SlNPV and azadirachtin and the lowest in Btk treated food. The same trend was observed for the weight of faeces voided. The feeding period was the maximum in untreated check and minimum in the Btk treatments.

The highest consumption index (CI) was recorded for the larvae that fed on sunflower leaves treated with azadirachtin @ 500 and 1000 ppm and the lowest in Btk treatment (Table 1). The relative growth rate (RGR) was higher in azadirachtin and SlNPV treatments. The efficiency of conversion of ingested food into body substances (ECI) was higher in Btk treatments followed by untreated check. Azadirachtin treatment recorded lowest ECI. The recorded net efficiency or ECD was higher in Btk treatments followed by untreated check. The AD was higher in Btk and untreated check. Azadirachtin and SlNPV recorded lower AD values.

The food consumption was the lowest in Btk treated food, which might be due to the damage caused to the midgut by Btk which serves as stomach poison leading to quicker mortality (Adang, 1991). The enhanced growth rate observed with azadirachtin and SlNPV on *S. litura* might be due to the development of larva in a prolonged disease suppressed condition than the normal ones (Galande and Ajri, 1997). In spite of the feeding deterrence showed by azadirachtin, the insect showed higher relative growth rate, which may be due to the altered metabolic regime in the test insect. Nucleopolyhedrovirus infected larvae have been reported to show prolonged juvenility, as the virus influenced the host via juvenile hormone activity (Ramakrishnan and Chaudhari, 1974; Subramanian, 2003).

The higher utilization of food material by *S. litura* in terms of ECI was on Btk treated food and the ECD or net efficiency was also higher in the same treatment. Naturally this condition refers to the stress situation caused by the pathogen, wherein

TABLE 1. Effect of selected biopesticides on feeding period and food consumption of third instar larvae of *Spodoptera litura*

Treatment	Feeding period (days)	Food ingested (g/larvae)	Faeces voided (g/larvae)	Consumption index (CI)	Growth rate (GR)	ECI (%)	ECD (%)	AD (%)
B. thuringiensis var. *kurstaki* @ 250 ppm	1.8^{a}	0.1564^{a}	0.0608^{a}	0.3271^{d}	0.0929^{d}	28.39^{a}	46.44^{a}	61.13^{a}
B. thuringiensis var. *kurstaki* @ 500 ppm	1.4^{a}	0.0986^{a}	0.0420^{a}	0.3574^{d}	0.0892^{de}	24.95^{b}	43.46^{b}	57.40^{b}
SlNPV @ 1×10^{7} POB ml^{-1}	4.6^{c}	1.5294^{d}	0.7496^{d}	1.1365^{b}	0.1437^{c}	12.65^{f}	24.80^{f}	50.99^{c}
SlNPV @ 1×10^{8} POB ml^{-1}	3.8^{b}	1.0304^{bc}	0.5246^{b}	0.9220^{c}	0.1636^{b}	17.74^{d}	32.38^{d}	49.09^{d}
Azadirachtin @ 500 ppm	4.6^{c}	1.2564^{c}	0.6488^{c}	1.6136^{a}	0.2237^{a}	13.87^{e}	28.67^{e}	48.36^{d}
Azadirachtin @ 1000 ppm	3.6^{b}	1.0160^{b}	0.5364^{b}	1.5979^{a}	0.1576^{b}	9.86^{g}	20.89^{g}	47.20^{e}
Untreated check	10.2^{d}	1.9810^{e}	0.9612^{e}	0.3899^{d}	0.0789^{e}	20.24^{c}	39.32^{c}	51.48^{c}
CD (0.01)	0.6997	0.3151	0.0595	0.0696	0.0105	1.0421	1.2793	1.0877

rates of ECD will be always faster than those of normal ones (Soo and Fraenkel, 1966). Further, it may be attributed that the cessation of feeding upon disease initiation and associated regurgitation by the larva might also have contributed to reduced food intake and feeding for a shorter period.

Index of digestibility level (AD) was highest for Btk. The reason attributed is the shortened feeding time on the Btk (Chandra *et al.*, 1999; Gujar *et al.*, 2000; Praveen and Dhandapani, 2001). Remaining treatments recorded lower AD values due to delayed mortality. It may be concluded that the *S. litura* larva is able to continue its feeding activity in spite of the contamination of the food material with biorationals indicating the slower killing effects of the biorational pesticides. However, the rate of feeding, levels of digestion and degree of assimilation varied with different biopesticides. Among them, Btk offered quicker mortality than SlNPV and azadirachtin. The damage caused by surviving larvae on leaves treated with all biopesticides was significantly lower than control. Given that the damage inflicted by the intoxicated larva is tolerable, for the long term benefits and for a sustained ecological pest management, the tested biorationals stand good.

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(Received 4 May 2006; accepted 15 February 2008)

ENTOMON 33(1): 75–78 (2008)
Short Communication No. ent.33110

Occurrence of Phthiraptera on the house crow, *Corvus splendens* (Passeriformes: Corvidae)

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ABSTRACT: The prevalence and other population parameters of five phthirapteran species on a sample of 70 house crows in the district Rampur, U.P., India were determined. The most prevalent species was *Philopterus lahorensis* (51.45% of the population), followed by *Allocolpocephalum fregili* (34.3%), *Corvonirmus saliemi* (30.0%), *Menacanthus gonophaeus* (18.6%) and *Myrisidea bakttitar* (11.4%). All the five species exhibited aggregated distribution but the distribution did not conform to negative binomial model. Females outnumbered the males in all the five species; the adult to nymph ratio varied among the species.

KEYWORDS: Phthiraptera, Mallophaga, biting lice, population parameters on crow

Prevalence and frequency distribution pattern of Phthiraptera on selected avian hosts has been recorded from time to time. Rozsa *et al.* (1996) compared the louse loads of territorial hooded crows *(Corvus coronoe cornix)* and colonial rooks (*C. frugilegus*). A survey of literature indicated that there was no report on the population levels of Phthiraptera infesting the house crows (*Corvus splendens*). The present report furnishes information on the prevalence and frequency distribution patterns of five phthirapteran species occurring on house crow.

For the present studies, fumigation method described by Clayton and Drown (2001) was adopted. As a deviation, polythene bags and chloroform were used instead of Anaesthesia jar and ethyl acetate, suggested in the method. The entire louse load was transferred to 70% alcohol and separated according to species, stage and sex, for further analysis. The data were used for determining the prevalence, mean intensity, sample mean abundance and variance to mean ratio of the louse population. The exponent (k) of negative binomial distribution was estimated with the help of software

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offered by Rozsa *et al.* (2000)). The goodness of fit between the observed and the expected frequencies (negative binomial) was determined by chi-square test.

A total of 2345 specimens belonging to five species viz. *Allocolpocephalum fregili* Denny, *Menacanthus gonophaeus* Burmeister, *Myrsidea bakttitar* Ansari, *Corvonirmus (=Brueelia) saliemi* Ansari and *Philopterus lahorensis* Ansari were recovered. Price *et al.* (2003) recognized only five phthirapteran species on the aforesaid host (*B. saliemi*, *C. fregili*, *P. lahorensis*, *Menacanthus gonophaeus* and *Myrsidea merisuoi* Eichler). In the present studies, *M. merisuoi* was not detected although. *M bakttitar* was recovered. Price *et al.* (2003) have mentioned the presence of *M. bakttitar* on a subspecies of *C. splendens* (*C. s. zugmayeri*).

Prevalence of Phthiraptera on house crows was 67.5% ($n = 70$). The overall mean intensity of Phthiraptera on the house crows remained 49.9 while the sample mean abundance was 33.5. *P. lahorensis* was the most prevalent species. The prevalence of different species in the order of descending frequency was *P. lahorensis* > *A. fjregili* > *C. saliemi* > *M. gonophaeus* > *M. bakttitar* (table 1). The mean intensities and sample mean abundances varied from 10.6 to 27.0 and 1.2 to 13.9, respectively. The values of variance to mean ratio exceeded unity in the case of all the five species. The prevalence of different phthirapteran species on Hungarian rooks and hooded crows (Rozsa *et al.*, 1996) appear to differ from that of house crows, recorded during present study. Furthermore, the infestation intensity of different species on Hungarian rooks (1–15) and hooded crows (3.9–4.9) were comparatively lower than house crows (10.6–27.0).

The values of negative binomial exponent (k) ranged from 0.03 to 0.2. The frequency distribution patterns were aggregated in case of all the five species but the observed frequencies failed to correspond the frequencies expected by negative binomial model. Survey of literature indicated that phthirapteran ectoparasites generally exhibit aggregated (clumped) distribution as most of the hosts have few parasites while a few have lots of them. However, Rekasi *et al.* (1997) found that distribution patterns of twenty one (out of 27 species, occurring on 13 birds) conformed to negative binomial model. But Saxena *et al.* (2007) and Gupta *et al.* (2007) reported that the frequency distribution pattern of only one species (out of 12 species, occurring on five avian hosts) conformed with the negative binomial model.

An examination of population composition (table 1) shows that female population outnumbered the males in case of all the five species. However, the adult to nymph ratios were quite inconsistent. It remained nearly equal in case of *A. fregili* and C. *saliemi*. Nymphal population dominated over adults in case of *P. lahorensis*. However, in case of *M. gonophaeus*, the adults outnumbered the nymphs in natural population. The examination of population composition of any species provides useful information about the temporal stability of the population; there will be fewer adults and more nymphs if the population is increasing (Marshall, 1981). However, the population composition (proportion of juveniles) is bound to vary with time, due to several environmental and host factors (Marshall, 1981). As far as sex ratio is concerned, there was considerable uniformity as the females outnumbered the males in case of all the

TABLE 1. Population of five species of lice on house crows (*Corvus splendens*) in district Rampur, U.P., India

Observations	*Allocopocephalum fregili*	*Menacanthus gonophaes*	*Myrsidea bakttitar*	*Philopterus lahorensis*	*Corvonirmus saliemi*
Total number of lice recovered	556	259	85	971	474
Total number of males	122	53	17	164	90
Total number of females	151	84	33	222	139
Total number of nymphs	283	122	35	585	245
Adult nymph ratio	1:1	1:0.9	1:0.7	1:1.5	1:1.1
Male female ratio	1:1.2	1:1.6	1:1.9	1:1.4	1:1.5
Ratio of nymphal stages	1:0.9:0.7	1:0.8:0.7	1:0.8:0.6	1:0.9:0.7	1:0.9:0.8
Number of birds infested	24	13	8	36	21
Prevalence (%)	34.3	18.6	11.4	51.4	30
Mean Intensity	23.2	19.9	10.6	27.0	22.6
Sample mean abundance	7.9	3.7	1.2	13.9	6.8
Variance/ Mean ratio	30.3	29.5	16.1	25.0	23.7
Range of infestation	5–72	1–58	2–26	2–56	3–48
k of negative binomial	0.11	0.05	0.03	0.2	0.09
Negative binomial (Yes/ No)	No	No	No	No	No

species. In phthirapteran population, sex ratios are generally female biased (Marshall, 1981). Unequal longevity (males generally short lived than females), sampling errors (being small sized, males are easily lost during sampling) and local mate competition (if female lice disperse more effectively than males) presumably cause imbalances in sex ratios of phthirapteran population (Marshall, 1981; Rozsa *et al.*, 1996; Saxena *et al.*, 2007).

ACKNOWLEDGEMENTS

We are thankful to the Principal, Govt. Raza P. G. College, Rampur for laboratory facilities and to the Department of Science & Technology, New Delhi, India for providing financial support to A.K.S. in the form of project No. SP/SO/AS-30/2002

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(Received 8 October 2007; accepted 15 February 2008)

ENTOMON **33(1)**: 79–81 (2008)
Short Communication No. ent.33111

Effect of row spacing and different levels of nitrogenous fertilizer on population density of thrips (*Thrips tabaci* Lind.) in onion (*Allium cepa* L.)

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ABSTRACT: A field experiment was conducted to find out the effect of row spacing and different levels of nitrogenous fertilizers on the population densities of thrips (*T. tabaci*) infesting onion. A spacing of 30 cm between rows and 150 kg/ha nitrogen had low level of thrips population and gave highest yield.

KEYWORDS: thrips, row spacing, fertilizers, population densities

Onion (*Allium cepa* L.) is an important condimental bulbous crop. It is a major horticultural cash crop grown in Rajasthan. Thrips (*Thrips tabaci* Lind.) is a major pest of this crop which causes considerable yield loss. Various agronomic and cultural practices play an important role in population build up of pest, slight modification in these practices will some times reduce the population density of insect pests greatly. Keeping the point trials were conducted to investigate the effect of different row spacing and different levels of nitrogenous fertilizers on the population density of thrips (*T. tabaci*) in onion crop.

The experiments were laid out at Experimental Farm of Krishi Vigyan Kendra, Chomu, Jaipur, Rajasthan during *rabi* 2005–06 and 2006–07 in randomized block design (RBD). Onion variety RO-59 was used for the trials.

An experiment was conducted to evaluate row to row spacing effect on thrips population in onion for two consecutive years, with following five treatments of row spacing i.e., 20, 25, 30, 35 and 40 cm, respectively. The seedlings were transplanted in 24 equal plots (8 × 10 m). All the treatments were free from insecticidal application. Agronomic practices were followed as per the recommendation. Data on the thrips population were recorded weekly from five randomly selected plants from each plot

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TABLE 1. Effect of row spacing on population densities of thrips in onion

Treatment (Row spacing in cm)	No. of thrips per plant		Yield (q/ha)	
	2005–06	2006–07	2005–06	2006–07
20 × 20	8.290	8.453	191.225	179.575
25 × 25	6.945	6.650	255.103	234.985
30 × 30	6.100	6.373	265.875	240.815
35 × 35	4.805	4.605	214.088	218.643
40 × 40	4.598	4.515	211.688	214.200
CD at 5%	0.236	0.182	56.222	73.432

TABLE 2. Effect of different levels of nitrogenous fertilizers on population densities of thrips in onion

Treatments (N:P:K)	No. of thrips per plant		Yield (q/ha)	
	2005–06	2006–07	2005–06	2006–07
(0:100:100)	7.618	7.820	108.225	100.650
(50:100:100)	7.518	7.455	120.988	123.025
(100:100:100)	7.588	7.668	141.675	135.625
(150:100:100)	7.855	7.928	155.613	144.625
(200:100:100)	13.293	14.238	111.325	111.525
(250:100:100)	13.343	13.793	94.933	89.213
CD at 5%	0.218	0.438	2.250	2.115

by plant wash method described by Bullock (1963) until the crop was harvested. After digging, yield from each plot was recorded.

A separate trial was conducted to evaluate the influence of five different levels of nitrogenous fertilizers on thrips population. The trial was conducted with six treatments — one control without NPK and remaining by the varying recommended dose of NPK fertilizers. N levels as 50, 100, 150,200 and 250, half applied at planting and balance 8 weeks after planting with P and K given full as basal dose. For counting thrips the plant wash method described by Bullock (1963) was followed. Yield from each plot was also recorded.

The maximum number of thrips (8.290 and 8.453 per plant) was observed in 20 × 20 cm spacing and the minimum in 35 × 20 cm and 40 × 20 cm spacing. The maximum yield (265.875 and 240.815 q/ha) came from 30 × 30 cm spacing. The lowest yield was recorded in 20 × 20 cm spacing during both the years. Edelson *et al.* (1986) reported a negative relationship between thrips population and onion yield. Yield data did not significantly vary in both the years.

Table 2 shows the influence of different rates of N with constant P, K levels on thrips population densities during the years 2005–06 and 2006–07. No effect was observed on thrips densities up to 150 kg/ha, while 200 and 250 kg/ha had the maximum

thrips densities (13.93 and 14.238; 13.343 and 13.793 thrips per plant, respectively). Fertilizers provide plants with more nutrients (Bentz *et al.*, 1995) as a result of which the plants not only get a lush green colour but also enhance the accumulation of nutrients in the shoots, which attract phytophagous insects. Use of fertilizers not affects the nutritive value of plants but also impacts the insect pests densities (Bentz and Larew, 1992). Onion yield showed a direct relation to the increased fertilizer rates up to 150 kg/ha. The maximum fertilizer rate of 250 kg/ha gave minimum yield of 89.213 q/ha. Excessive use of chemical fertilizers might have caused disturbance in physiological activities of the plants that adversely affect the yield (Megdi *et al.*, 2001). The treatment 150 kg/ha gave the maximum yield (155.613 and 144.625 q/ha) during both the years of study. For the proper growth of plants an optimum rate of nutrients is very important (Nashrin *et al.*, 2001). On the basis of the results it is clear that thrips are not a threat if the fertilizers are used in low or optimal rates. Under the present study the 150–100–100 NPK kg/ha is the best fertilizer rate for onion yield and low thrips infestation.

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(Received 13 August 2007; accepted 15 February 2008)

ENTOMON 33(1): 83–86 (2008)
Short Communication No. ent.33112

Pests of economic importance on *Jatropha curcas* L., a biodiesel plant in Andhra Pradesh, India

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ABSTRACT: Large-scale cultivation of *Jatropha curcas* is being taken up in Andhra Pradesh, India as a source of biodiesel. An attempt for an inventory of pests causing significant damage to *J. curcas* plant is made for the first time in Andhra Pradesh. Damage by the twig girdler, *Oncideres limpida* on *J. curcas* is reported for the first time in India. Five species of insects viz., thrips, *Retithrips syriacus* (Mayet); spotted plant bugs, *Scutellera nobilis* (Fabricius) and *Chrysocoris purpureus* (Westwood); soft scale, *Megapulvinaria maxima* (Green); inflorescence webber and capsule borer, *Pempelia morosalis* (Saalm Uller) were also seen severely infesting *Jatropha curcas* (L.) in Andhra Pradesh. Their seasonal incidence, nature and extent of damage also have been described.

KEYWORDS: *Jatropha curcas*, biodiesel, pests, Andhra Pradesh

Jatropha curcas (L.), commonly known as physic nut is a medicinal plant, hedge crop and also widely used in soap industry. More importantly, the oil extracted from seeds is a promising substitute for diesel. As per the estimates of Ministry of Rural Development, Government of India the potential area for Jatropha cultivation in Andhra Pradesh is 43.96 lakh ha, and it is the target of Government of Andhra Pradesh to raise biofuels in 2 lakh ha across the state by 2008–09 (Kureel, 2006). Information available on the pest scenario on *J. curcas* from Andhra Pradesh is inadequate for the future crop protection needs relating to the crop. Hence, the present study was aimed at making an inventory of pests that cause economic loss to *J. curcas* in Andhra Pradesh. Fortnightly observations were made during 2005–06 on 30 randomly selected plants from a 3 ha block of two year old *J. curcas* in the Hayathnagar mandal of Rangareddy district, Andhra Pradesh. No pesticides were sprayed on the selected plants.

Oncideres limpida (Coleoptera: Cerambycidae), the twig girder was one of the serious pests observed on *J. curcas*. Branches close to ground at two feet height and having thickness between 12 and 21 mm were the worst affected. The adult beetle chews a continuous notch girdling the twig. The girdles are similar to that made by

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a saw and the ends appear gnawed almost straight across with a faint rounding. The girdled twig soon dries out and breaks off; and the larva develops inside the fallen twig on the ground. The incidence of girdler was recorded mainly during October–November. The number of affected branches on each plant was in the range of 2–8 and about eight percent of the plants in the experimental block were found affected. The female beetles of *O. limpida* damaging *Prosopis juliflora* has been reported earlier from Rajasthan (Singh, 1993). This is the first report of *O. limpida* on *J. curcas* in India.

Retithrips syriacus (Mayet) (Thysanoptera: Thripidae) occur as colonies on leaves and tender fruits. Adults and nymphs cause damage by scraping the epidermal tissue and suck sap from leaves and fruits, resulting in white patches, which are visible from a distance. The damaged portions on the fruits turn into black patches and often lead to secondary infection of powdery mildew. Severe foliar infestation resulted in premature leaf drop. It occurs all through the year except March and April. Peak incidence was in May-June and again in November-December. The mean number was in the range of 35 to 250 and adult nymph ratio was 3.2: 29.4. Heavy rains during July–August diminished their population and the plants recovered their natural vigour. This species was first reported in India by Seshadri and Ananthakrishnan (1954). Later it was reported on many crops *viz.*, grapevine, groundnut, pomegranate, and cashew and rose (Nair, 1975; Dash and Naik, 1998). However, the incidence of *R. syriacus* on Jatropha was first reported by Manoharan *et al.* (2006) from Tamil Nadu and the present report is for the first time from Andhra Pradesh.

Scutellera nobilis (Fabricius) and *Chrysocoris purpureus* (Westwood) (Scutellaridae: Hemiptera) are the two species of bugs found infesting *J. curcas*. Both the bugs are metallic blue-green in colour with 8–12 black spots on the dorsal side of thorax and abdomen. Their incidence was noticed throughout the year, but high population was recorded during August–November and the mean number of adults per plant was between 2 and 15. Eggs are pink in colour, found in groups on the leaves. On hatching the pale red grubs with black patches on thorax move all around the plant in groups and suck sap from leaves, flowers and fruits. Feeding on inflorescence caused premature flower drop. Attack on fruits left pinholes, which further lead to rotting of the rind and eventually fruit drop. The seeds from affected fruits were chaffy. *S. nobilis* has been reported infesting tamarind in Madhya Pradesh (Meshram and Garg, 1999) and cotton in Haryana (Sucheta and Khokhar, 2004). On *J. curcas* the incidence of *S. nobilis* had been reported from Tamil Nadu (Manoharan *et al.*, 2006) and Uttar Pradesh (Chitra Shankar and Dhyani, 2006) in India.

Infestation by soft scales *Megapulvinaria maxima* (Green) (Hemiptera: Coccidae) causing white scabs on leaves and twigs were common. All stages except the newly hatched nymphs are sessile. Movement of ants on the plants was the first indication of scale infestation. *M. maxima* incidence was observed from August to February. The peak infestation was in October and November. Infested plants often showed growth of black sooty mold. Severe incidence of *Pulvinaria maxima* on *Jatropha* sp. and other plants like neem, cotton and mulberry was reported by Ayyar (1919) in

Andhra Pradesh. It was reported as a serious pest on neem (Annamalai *et al.*, 1996) and more recently on *J. curcas* in one location out of the three surveyed in Tamil Nadu (Manoharan *et al.*, 2006).

The larvae of inflorescence webber and capsule borer, *Pempelia morosalis* (Lepidoptera: Pyralidae) occur in groups and feed on leaves, inflorescence and tender buds by making silken webs. The damage was severe on inflorescence and fruits. The seeds in the affected fruits were either partly or completely damaged resulting in heavy yield loss. Jatropha is an indeterminate crop and it comes to flowering many times a year depending on climate and availability of soil moisture. Peak incidence of webber was recorded in February–March and August–September, coinciding with flowering on Jatropha. The number of webs per plant ranged between 3 and 11 and the number of larvae in each web between 6 and 30. *Salberia* (*Pempelia*) *morosalis* (Saalm Uller) was first reported from India as leaf and flower webber on few forest plants including *Jatropha* by Beeson (1941). More recently it has been reported as capsule borer and bark-eating caterpillar on *J. curcas* from Uttar Pradesh (Chitra Shankar and Dhyani, 2006). This is the first report of *P. morosalis* infesting *J. curcas* in Andhra Pradesh.

ACKNOWLEDGEMENTS

We are grateful to NOVOD Board, Gurgaon for financial assistance and the Director and Heads DCS and DRM, CRIDA, Hyderabad for providing necessary facilities. The services rendered by Prof. C. A. Viraktamath, UAS, Bangalore and Prof. S. Suresh, TNAU, Coimbatore in identifying the insect specimens is gratefully acknowledged.

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(Received 26 December 2007; accepted 15 February 2008)

ENTOMON **33(1):** 87–88 (2008)
Short Communication No. ent.33113

Incidence of shot hole borer, *Xylosandrus compactus* Eichhoff (Coleoptera: Scolytidae) on wilt disease affected cocoa

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ABSTRACT: Extensive wilting of cocoa trees has been reported from Mysore, Chamrajanagar, Bangalore and Mandya districts of Karnataka. The wilted trees showed shot hole borings made by *Xylosandrus compactus* on the dead twigs. All the stages of the pest were found in the galleries made by the pest in twigs. The life cycle was completed in 28 days in laboratory. Twigs of 11–20 mm thickness were preferred over those below 10 mm and above 30 mm in thickness. Since the incidence was observed only on dead twigs the association of pest incidence and the wilting could not be established.

KEYWORDS: *Xylosandrus compactus*, cocoa wilt, *Ceratocystis* sp.

Wilting and rapid death of cocoa (*Theobroma cocoa*) trees has been reported from Mysore, Mandya, Chamrajnagar and Bangalore districts of Karnataka during 2000 (Chowdappa *et al.*, 2002). The etiology of this disease is still unknown. Occurrence of shot holes caused by *Xylosandrus compactus* was observed in the field in Mysore district of Karnataka. In India there is no record of this species infesting cocoa but it has been recorded as a primary pest on coffee seedlings (Muthappa and Venkatasubbaiah, 1981). Hence preliminary studies were carried out and the findings are reported here.

The occurrence of beetle infestation in relation to stem thickness was assessed. Twenty twigs of 25 cm length and girth of 5–10 mm, 10–20 mm, 20–30 mm and > 30 mm were collected randomly from 20 plants in wilt infested gardens. Collection was made randomly from all the four directions. Mean number of shot holes in these samples was recorded in relation to the girth of the stem. The mean holes in twigs having 5 to 10, 11 to 20, 28 to 30 and > 30 mm thickness were 0.8, 4.05, 2 and 0 respectively.

The twigs having the bore holes contained all stages of the pest in the gallery. The pest was reared in the laboratory on wilted cocoa twigs to study the biology. The egg,

larval and pupal periods were observed as 3.8, 5.3 and 8.66 days, respectively, the total being 28.5 days.

In India *X. compactus* was reported as a primary pest on robusta coffee and its attack was confined to seedlings (Muthappa and Venkatasubbaiah, 1981). In cocoa the incidence was more on 4–5 years old trees. The biology of this pest was reported on coffee in Ivory Coast (Brader, 1962) and Hawaii (Hara and Beardsley, 1979) and on cocoa in Nigeria (Gregory, 1954). Sixty species of ambrosia beetles have been recorded to infest cocoa twigs and majority of them have been recorded as secondary feeders. Of these only *X. ferrugineus* F. attacks healthy cocoa. *X. corniculatus* Schedl and *X. posticus* Eich. attack diseased or dead trees only (Entwistle, 1972).

In Karnataka the incidence of *X. compactus* was restricted to wilt affected trees. Hara and Beardsley (1979) reported that stressed plants were more susceptible to infestation by scolytids. The attraction of ambrosia beetles (especially *Xyleborus*) to diseased plants of *Mangifera* and *Eucalyptus* were reported earlier (Entwistle, 1972). Association if any between *Xylosandrus compactus* and the wilt disease of cocoa in Karnataka can be established only with further research.

ACKNOWLEDGEMENTS

The authors are thankful to Cadburys India for assisting in field observations at Yelwala. The technical assistance provided by Mr. P. Ravindran, CPCRI, Kasaragod is acknowledged.

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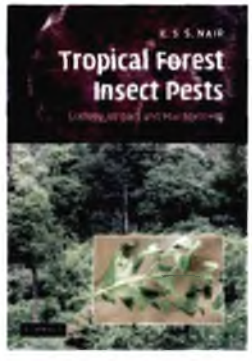
(Received 27 November 2007; accepted 15 February 2008)

REVIEW OF BOOK



Tropical forest insect pests

Ecology, Impact, and Management

K. S. S. Nair
Cambridge University Press, UK
Published 10 May 2007, 422 pp.

Though we have a few recent books published in Tropical Forest Entomology, the present one under review is unique because it is written by an author, who has a first hand field knowledge on the various issues related to forest pest problems in the tropics. Moreover, Dr. K. S. S. Nair with his abilities both as a teacher and researcher is an apt person to write a book like this.

The forest is an abode of rich biodiversity of insects. With the onset of large scale forest plantations coming up, it has caused pest problems as well, which are different from that of the agriculture sector. Thus developing pest control strategies in forest plantations is a challenging problem. In forestry, considerable data on the pest ecology would be required to decide on even the methods to be adopted for managing the pest. Thus success stories on pest management in forestry are limited.

As the author himself has indicated in the text "Forest entomology is rich in theories". It has to be further added that most of these are based on case studies from temperate forests. In contrast, the examples which are lucidly presented in this book are from the tropics.

The introductory pages of this book set the stage for discussing the varied interactions between the forest insects and their habitat. The initial chapter describes the tropics, tropical forest types, species diversity, forest growth dynamics, management practices, non-timber forest products and also issues such as deforestation, sustainable management, plantations and exotics. Under structural diversity, 30 orders are

presented with details on six major insect orders of forestry importance. Seven feeding guilds are also presented to explain the functional diversity. The term pest has also been adequately explained. The functional role of insects in the flow of matter and energy in the forest ecosystem is described and also the two existing theories on insect pest outbreaks-'Resource supply theory' and 'Host concentration theory' are explained.

The book also has a separate chapter on pest incidence in natural forests with many case studies from across the globe. The insect pest problems in tropical forest plantations have also been covered in detail. There is a very useful chapter on the pest scenario of twenty four tree species giving the details of the tree species, pest spectrum, impact of pests, management aspects and knowledge gaps. This chapter will be an updated source of reference for researchers, teachers and students of forest entomology.

Three much debated and controversial aspects – pest incidence in natural forests *vs.* plantations, exotics *vs.* indigenous tree species and monocultures *vs.* mixed plantations, have been dealt with in a very balanced manner.

Most of the entomologists have a pet experimental insect and in forestry, choosing a pet insect is quite difficult. But Dr. Nair, because of his inherent interest in population dynamics of insects, rightly chose the teak defoliator, *Hyblaea puera* as his pet insect and worked relentlessly towards finding out a viable control strategy by understanding the ecology of this pest. The formulation of the pest evolution hypothesis to explain the greater incidence of pest outbreaks in plantations than in natural forests is helpful in evolving control strategies. *H. puera* is a major pest problem in most of the teak growing countries, especially in the tropics. The descriptions given on various aspects of the ecology of this pest shows his in depth field knowledge and they are exactly like what you find in a field situation.

Illustrations and photographs in the book are excellent and would have been more impressive, if printed in colour. The book also contains over 500 references of great relevance for anyone to read and understand more on specific topics in forest entomology. Thus this book is an important addition to the tropical forest entomology literature which would enthuse youngsters to take up serious studies on the ecology and management of forest insect pests.

Excerpts from the book can be viewed at `www.cambridge.org/9780521873321`

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Introduction should be brief, normally not exceeding 300 words. Include the specific aim of the research, a review of the available information in the area and existing gap in knowledge. The introduction should thus justify the work carried out. Avoid elementary details and repetition of well known facts. For example, in a paper reporting the efficacy of a biopesticide against a particular pest, it is not necessary to explain the hazards of chemical pesticides, alternative methods of insect control and advantage of integrated pest management. Limit the literature review to what is most relevant to the topic under study.

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Krishnaswamy (1978, 1979)

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(Reddy 1978; David 1991)

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Nayar K. K. (1953) Neurosecretion in *Iphita*. Current Science 22(2): 149.

Nair M. R. G. K. and Mohandas N. (1962) On the biology and control of *Carvalhoeia arecae*, a pest of areca palms in Kerala. Indian Journal of Entomology 24: (1) 86–93.

Jalaja M. Muraleedharan D. and Prabhu V. K. K. (1973) Effect of extirpation of median neurosecretory cells on reproduction in the female red cotton bug, *Dysdercus cingulatus*. Journal of Insect Physiology 19(1): 29–36

Books and Articles in Books:

Novak V. J. A. (1966) *Insect Hormones*. Methuen and Co., 478 pp.

Wigglesworth V. B. (1964) The hormonal regulation of growth and reproduction in insects. In: *Advances in Insect Physiology* Vol. 2 (Eds. Beament J. W. L., Treherne J. E. and Wigglesworth V. B), Academic Press, London, pp 247–335.

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(Form IV, Rule 8 of Registration of Newspapers (Central) Rules 1956)

1. Place of publication:	Trivandrum
2. Periodicity of publication:	Quarterly
3. Printer's name, nationality: and address:	D. Muraleedharan, Indian CABB, University of Kerala Kariavattom, Trivandrum 695581
4. Publisher's name, nationality and address:	-do-
5. Editor's name, nationality and address:	-do-
6. Name and address of the individual who owns the newspaper:	Association for Advancement of Entomology CABB, University of Kerala Kariavattom, Trivandrum 695581

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D. Muraleedharan
Publisher, ENTOMON

Trivandrum
31 March 2008

Reg. No. 123SBN

Edited, printed and published by D. Muraleedharan for and on behalf of Association for Advancement of Entomology, CABB, University of Kerala, Trivandrum. Typeset in TEX by River Valley Technologies, Trivandrum. Printed at St. Joseph's Press, Trivandrum